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THE WAR OFFICE

RESUSCITATION

EQUIPMENT, ORGANIZATION, TRAINING
AND
PROCEDURES
1944

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RESUSCITATION

EQUIPMENT, ORGANIZATION, TRAINING AND PROCEDURES

Since it is the policy of the Army to train a special medical officer with each medical unit in the ætiology, pathology and treatment of Wound (syn. Traumatic, Hæmorrhagic, Secondary) Shock, there are in this booklet some recommendations concerning the duties of this officer, the equipment needed, the personnel required to assist him and the organization he should endeavour to establish to enable him to carry out this important work. The officer should also refer to M.R.C. War Memorandum No. 1, produced in co-operation with the Army Medical Service, " The Treatment of Wound Shock " (H.M. Stationery Office, London).

WOUND SHOCK, RESUSCITATION AND TRANSFUSION

WOUND SHOCK—DEFINITION

A state of lowered vitality following upon injury, manifesting itself by general and peripheral symptoms, due to circulatory embarrassment, which frequently progresses, to terminate in circulatory failure.

CIRCULATORY COLLAPSE IN CASUALTIES—TYPES OF " SHOCK "

A considerable number of ætiological factors may be concerned in the production of the clinical picture, loosely and conveniently termed " Shock." Failure to appreciate this accounts for much of the controversy on the relative merits of different therapeutic measures employed in resuscitation. The following causes of circulatory collapse may operate in wounded men, and should be considered by any medical officer assessing a case of " Shock."

1. Oligæmic Shock

Due to reduction in blood volume from direct blood loss, either externally or into the tissues, or plasma loss at the site of an injury, or into burned or crushed tissue, or, to a combination of both types of loss.

2. Neurogenic Shock

At one time called " primary shock." Seen in its simplest form as a straightforward faint. Due to painful stimuli, with or without injury, or mental stress, which initiate a reflex nervous mechanism manifesting itself by a low blood pressure and a *slow pulse*. May be a complicating factor in oligæmic shock. There is no reduction in blood volume. Two types are recognized :—

(*a*) Vaso-vagal syndrome—a simple faint.

(*b*) Cerebral type—seen in cases of severe head injury associated with low blood pressure and slow pulse.

3. Toxic Hypotensive

Due, for example, to fulminating infection, such as peritonitis from a ruptured viscus or acute gas gangrene of a wounded limb. Caused entirely by toxæmia and unaccompanied by reduction in blood volume. Experience now suggests that large wounds involving much soft tissue may be a source of toxic hypotensive substances.

4. Mechanical

Due to circulatory disasters, such as coronary thrombosis, or mechanical factors, such as pulmonary embolism, fat embolism and thoracic injury, including blast effects. There is no reduction in blood volume.

5. Dehydration

Gross dehydration from low fluid intake followed by profuse sweating, excessive vomiting and diarrhœa, may seriously deplete blood volume, and lead to a state the equivalent of oligæmic shock. Rare, but may be met with in tropical countries, especially as a factor contributing to oligæmic shock and hindering natural recovery.

6. Carbon Monoxide Poisoning

Not uncommon under war conditions in casualties injured in a confined space to which escaping coal gas or explosive gases have access or in a burning building. Symptoms of shock arise from toxic myocardial changes and from pulmonary œdema.

Under war conditions, many of these types may be met with either singly or combined. By far the commonest is obviously the OLIGÆMIC type brought about by bodily injury, with subsequent blood and/or plasma loss. Additional toxic factors may be prominent with large wounds.

In defining the various types of " shock," stress has been laid on the occurrence or absence of blood volume reduction. This is because transfusion is rightly regarded as the most common single specific for the resuscitation of the majority of injured men, but only when the cause of all or part of the condition is a gross reduction in blood volume. Treatment of " shock " must be governed by cause because shock is not a specific condition for which there is a set routine treatment. Let the medical officer, therefore, catechise himself as to cause before he initiates treatment and when he is assessing the results. He will then hold the keys to success.

CLINICAL PICTURE

(*a*) Classical Case—Oligæmic Shock from simple acute hæmorrhage

A sequence of events follows acute blood volume reduction from simple hæmorrhage. The symptoms and the seriousness of the state are progressive and dependent on the amount of loss. Some hours are usually required for the full development of the unmistakable picture, but in others the onset may be quick and deterioration rapid. It is important to make an estimate of the phase which a case has reached as well as to realize that gross circulatory embarrassment as shown by a falling blood pressure, is a late and serious phenomenon which should be forestalled wherever possible.

The immediate reaction to acute and severe blood volume reduction is intense peripheral and visceral vasoconstriction, enabling the circulation to make the best use of such blood as remains. Thus the patient appears *intensely pale* and the periphery is *cold.* At the same time, by reflex action, through vagal and sympathetic centres, the *pulse becomes rapid, sweating* is marked and there may be a tendency to *vomit.* Consciousness of *pain* is very variable. The mental state, though sometimes *apathetic,* is more often deceptively *alert* and euphoric though sometimes tempered with apprehension or an ominous garrulity. Nature's first attempt at repair is to absorb tissue fluid into the circulation in an effort to restore blood volume ; this leads to a sensation of *thirst.* The natural process of repair takes many hours to be effective and in cases of severe blood loss cannot be accomplished quickly enough to prevent circulatory collapse. In these circumstances, a vicious circle then begins. There is loss of compensatory vasoconstriction (or constriction inadequate to compensate) leading to imperfect cardiac filling and inadequate cardiac output, manifested by a *falling blood pressure, peripheral cyanosis* and other early signs of circulatory failure which, unless treated, will soon lead to an irreversible state, and finally to death.

(*b*) Variable Features

Neither the presence nor absence of the symptoms italicized above is an exact indication of the gravity of the condition. The falling blood pressure is always a definite and ominous sign, but individual capacity for compensatory vasoconstriction is a variable feature ; it may be intense and maintain the blood pressure for a time, only to collapse suddenly and precipitate a more serious state than if the deterioration had been gradual. Some, indeed, react to blood volume reduction by overcompensation, so that even in the presence of serious injury, the blood pressure may occasionally be deceptively high. Some react to blood loss with a slow pulse instead of a fast one, and the pulse rate cannot be accepted as a reliable sign of the condition. Likewise, the peripheral manifestations of pallor, sweating, coldness and cyanosis may be variably exhibited.

Under war conditions, with large wounds and gross tissue damage, features such as toxæmia from infection or damaged tissue almost always modify the picture of simple acute hæmorrhage as well as the expected response to treatment.

AGGRAVATING FACTORS

Serious symptoms of circulatory collapse may be hastened, aggravated or precipitated by fear, by fatigue, by exposure to cold, by pain, by movement, particularly painful movement of an injured part, by dehydration, by continuing or renewed blood loss, by infection, by too much morphine, and by an anæsthetic.

ASSESSMENT AND SURVEY OF THE CASE

Ideally, the treatment of "shock" should "begin before its onset" for he who awaits the fully developed clinical picture with definite circulatory disturbance and the blood pressure at a dangerously low level, will have many disappointments. Late cases have frequently reached what is known as the irreversible state of which treatment is all too often unsuccessful or only temporarily effective. The good clinician should, therefore, recognize not only the definitely established condition, but also the prodromal features which may be expected to precede it, facts such as the types of wounds which are known to lead inevitably to it, features which may mask symptoms and signs, as well as aggravating and contributory factors. He should bear in mind that though oligæmia is the commonest cause of "shock" under war conditions, the other causes already described may nevertheless operate singly or in combination. *Assessment on common-sense grounds according to the extent and severity of the injuries and the general condition of the patient is more important than any one particular sign or symptom.* Most information is given by the reaction to treatment. Serial observations as to general condition and such recordable features as pulse and blood pressure are the most informative. Cardinal points for the preliminary assessment are to determine whether it is possible to arrest hæmorrhage, to immobilize an injured part and to relieve a mechanical factor such as a sucking wound of the chest. After this, the main decision is whether symptomatic treatment needs to be supplemented by more active treatment, such as transfusion, to the extent of the facilities available. When there is gross oligæmia the need is obvious, bearing in mind that a number of factors may intrude to reduce or nullify the expected effect (infra). The main object of the assessment is to ensure, as far as possible, that the patient reaches the surgeon in good condition for operation and this may require good judgment as to when to transfuse, when to evacuate, and whether to provide for transfusion during evacuation.

ORGANIZATION FOR RESUSCITATION WORK

Prompt treatment saves many lives. Preparations should, therefore, be as complete as possible, so that there is no delay once a casualty has been received. Fixation of responsibility is desirable. The appointment of a resuscitation officer and the allotment of a trained staff is advisable in any unit where there are facilities for the more elaborate types of treatment. A high degree of co-operation and mutual confidence between the admitting officer, the resuscitation officer and the surgeon is essential if large numbers of wounded are to be completely and rapidly treated. A separate resuscitation ward is required for orderly and smooth work. This, wherever possible, should be sited near to both the admission point and the operating theatre and be furnished with its own supply of beds and trestles, as well as instruments and drugs (*vide* treatment). In smaller units, which operate in forward areas, a knowledge of what can be done to forestall serious deterioration should be universal, whilst the facilities for the symptomatic and conservative treatment of shock need to be provided.

TREATMENT

The principles of treatment are to relieve symptoms, reduce or remove aggravating factors, and deal with the primary cause. This last in battle casualties will usually be oligæmia from blood loss. Hence, the most frequent single requirement for arresting the progressive deterioration in general condition is adequate and prompt restoration of blood volume, and thereby of tissue metabolism. Wherever possible, this must be preceded by or combined with control of hæmorrhage, otherwise the improvement in condition can be no more than temporary or can only be maintained by transfusing at a rate greater than the rate of loss. Early operation is also an important factor favouring survival in cases with very large injuries.

Treatment may be conveniently divided into :—

(*a*) *Symptomatic and Conservative.*—Applicable to all wounded men no matter what form of circulatory collapse they are suffering from, and available for use under almost any working conditions.

(*b*) *Specific and Active.*—The treatment required for the complete relief of oligæmic shock which calls for bulky equipment, including facilities for transfusion, and which is best combined with provision for prompt surgical treatment and after care.

Symptomatic and Conservative

General.—Restoration of peace of mind by encouragement and reassurance is important and should be positively practised ; it assists in stabilizing nervous factors and in permitting manipulations associated with treatment. All movement must be gentle and reduced to the minimum. Orderlies need to develop the deliberate, purposeful, but gentle, technique of a good nurse. Movement of injured parts must be avoided. Immobilization is a primary duty at the first opportunity, and this should not be tampered with unnecessarily. Wet clothing should be cut off, provided dry and preferably warmed covering can be provided. A large pair of scissors is essential when clothing is removed for any purpose. All wounded, except walking cases, should be placed in the lying position with the foot of the stretcher raised. Exceptions are abdominal cases and head wounds, which are better lying flat, and certain chest injuries, some of which are more comfortable when propped up, and others when lying on the side with the head low, in order to assist drainage of blood and mucus. Disturbance from noise and movement must be reduced to the minimum and the patient encouraged or helped to sleep.

Relief of Pain and Restlessness.—Pain aggravates both oligæmic and neurogenic shock. When pain is prominent it will be necessary to use morphine, which is of exceptional value when used with discrimination. It should be borne in mind, however, that whereas morphia will relieve pain, allay restlessness and encourage sleep, it will also cause respiratory depression, histotoxic anoxia, a fall in blood pressure and an increased tendency to vomit and sweat. The object is to attain the beneficial effects but avoid the disadvantages.

Morphia is contraindicated with penetrating abdominal wounds unless the diagnosis is quite clear. It should be given only in small doses to head wounds (⅙ gr.). Morphia should be given to chest injuries if they are in pain ; abolition of the pain assists the cough up of blood and mucus. An almost immediate morphine effect can be obtained (regardless of the state of the circulation) by intravenous injection. Up to ⅙ gr. may be administered intravenously ; it should be diluted with sterile water to about 1 ccm. and injected slowly (Army Injectio-morphinæ : gr. ⅙ in ♏.vii. is eminently suitable).

The dose should not be repeated until at least four hours later, and the size of dose, with time of administration, must always be clearly recorded on the Field Medical Card or on the patient's forehead if the danger of excess dosage is to be eliminated.

As an alternative to the intravenous route, ¼–½ gr. may be given subcutaneously or intramuscularly or placed under the tongue. Of these routes, the intramuscular is probably the best in the presence of severe shock when the circulation is feeble and absorption abnormally slow. But even so, the result may be disappointing and there is considerable temptation to repeat the dose too quickly. If this be done and at the same time the circulation be restored to normal by transfusion, a rapid absorption of a large dose may have serious effects.

Administration of Fluids.—Most battle casualties are dehydrated to some extent and complain of thirst ; this may reach an intolerable point if there has also been great loss of blood. Administration of fluid not only relieves an unpleasant symptom, but is also of first importance for assisting the natural restoration of blood volume. *If sufficiently hydrated with frequent drinks, those who have bled only a moderate amount may restore their own blood volume spontaneously. Drinks should be freely given to all save those who are unconscious or who have abdominal wounds.* Frequent small amounts are advisable when vomiting occurs. The best fluids are hot sweet tea, hot coffee, water, or any other non-alcoholic drink. As it is impossible to lose body fluids without losing salts, all drinks should contain half a teaspoonful of salt to the pint. Drinks should be provided at all

R.A.Ps. and casualty collecting posts along the chain of evacuation, including motor ambulances. Casualties too weak to lift a cup or in whom morphia has dulled thirst, must be helped and encouraged to drink. For these, an automatic delivery device (*e.g.* enema can with rubber tube or pail with tube to act as a straw) is a great help. The source of fluid should be below the level of the mouth, to avoid the danger of siphon action. In general, a wounded man requires at least eight pints of fluid in the twenty-four hours following wounding.

Rectal administration may supplement the oral route ; it has the advantage that neither complicated apparatus nor carefully prepared fluids are required.

Warmth.—Warming is undoubtedly beneficial to those suffering from cold and exposure, but if vigorously applied as a routine ritual in the treatment of oligæmic shock, it may do great harm. A " shock cage " can be hardly less lethal than a baking oven. It has already been stated that an important protective reaction to blood loss is an intense peripheral vasoconstriction which automatically gives rise to peripheral coldness. Excessive warmth causes peripheral dilatation with a diversion of blood to the non-essential periphery, an increase in the capillary bed and often a dangerous fall in blood pressure with sudden collapse, unless its application be simultaneously associated with blood volume restoration. Common sense is necessary. The comfort of the patient is the best guide. Wet clothing should be removed, and dry, warm pyjamas substituted ; draughts should be eliminated ; dressings should be performed with the minimum of exposure ; warm drinks should be given. The case should be placed in a warm bed, wrapped in blankets, supplemented by hot bottles or bricks to the point of comfort.

More vigorous methods (shock cages and primus stoves) should not be used unless the environmental temperature makes them necessary. Warming should never be enough to cause sweating. Limbs with injured main vessels, with a crush injury, with an established infection, or on which a tourniquet has been placed, should never be warmed. Warming of unconscious patients is particularly dangerous, as they are unable to give warning of distress. The virtue of reasonably applied warmth is seen to best advantage when it is combined with blood volume restoration by transfusion.

Oxygen.—Patients with chest wounds in whom blood oxygenation is impeded, benefit greatly from the administration of oxygen (hæmothorax, pneumothorax, fluid in air passages, gas casualties). Oxygen supplies in field units should largely be reserved for such cases.

Most casualties with severe oligæmic shock show some degree of cyanosis (stagnant anoxia) and some improvement in this, as well as in comfort, may be achieved by oxygen administration. The treatment, however, is only palliative and is not a specific directed towards eliminating the primary cause. Many will not tolerate the application of a BLB mask, the only efficient method of administration, which itself calls for careful nursing and attention (p. 64). To be efficient, the oxygen must be administered at a rate of six to seven litres a minute, which exhausts a 40 cu. ft. cylinder in two to three hours. Oxygen is not required as a routine in field work. It is of considerable value as a post-operative measure.

Specific and Active Measures—Transfusion

Early, adequate and permanent restoration of blood volume is the fundamental treatment of oligæmic shock. The procedure is not, however, entirely a mechanical one. Questions as to when to transfuse, what fluid to use, how much to transfuse and how fast, need to be considered, as well as the circumstances under which transfusion may fail or be deleterious.

When to Transfuse.—Ideally, restoration of blood volume should begin as soon as the diagnosis of oligæmic shock is made. Those who are severely injured or who have obviously suffered gross blood loss need to be transfused regardless of the blood pressure, and those in whom the pressure has already reached a low figure (80 mm. or less sys.) likewise brook no delay. In less severe cases, considerable clinical judgment is necessary. In general, if the blood pressure be obviously declining or if it remains below 100 mm. sys. for one hour, transfusion should no longer be delayed. Ideally, the restoration of condition should be followed by immediate surgery during and after which the patient may need to be maintained by further transfusion.

Some modification of these ideals is necessary under battle conditions because modern developments in apparatus and technique enable transfusions to be given much further forward than surgery can be practised. Transfusion in a forward area may be life-saving. At the same time, there is little point in fully restoring a casualty in a forward area, only for him to deteriorate from continuing hæmorrhage during a subsequent ambulance journey and arrive at the surgical point requiring to be revived again. Such secondary transfusion is always less effective and more difficult than on the first occasion. Forward transfusion needs great judgment as well as the choice of time for evacuation.

Transfusions during an ambulance journey have been successfully exploited (pp. 60, 61). All that is required is an orderly in attendance to shut off or regulate the flow, as required, and some device for fixing the bottle and apparatus, to prevent swaying ; the simplest method is to suspend the bottle from the ventilator with bandages, and to anchor the apparatus with bandage tied to a full petrol can of water (Fig. 18). Many casualties will require no more than to be embarked at once in an ambulance with a transfusion in progress. Others can be partially restored in a forward area, leaving the ambulance transfusion to complete the work. This should bring the case to the surgeon in good condition and permit him to operate within a few hours of wounding, which, especially with large wounds, is the most favourable period. Every attempt to control hæmorrhage should be made before the journey is undertaken.

Choice of Fluid.—Permanent blood volume restoration can only be achieved with a protein fluid. Crystalloid solutions (saline, etc.) remain only temporarily in the circulation, being quickly absorbed into the tissues or excreted ; as such they are invaluable for the treatment of dehydration, but not for oligæmic shock.

Theoretically, blood is the best fluid for those who have suffered blood loss, whilst plasma or serum, fluid or dried, is best for those who have lost plasma (burns, crush injuries). But the fundamental requirement is volume restoration, rather than oxygen carrying power. With volume restoration the improved circulation enables the best use to be made of such blood as remains. Death from lack of oxygen carrying power is rare provided volume be restored. Hence the theoretical necessity for blood is not essential in practice, nor is it altogether desirable, in that there is considerable evidence that an embarrassed circulation responds better at the outset to the introduction of the more natural and less viscid fluid, plasma. In practice, too, blood is less readily available in the field because the supply of large amounts of safe stored blood requires a highly complex system of collection, delivery and storage. Experience has shown that the collection of fresh whole blood from the walking wounded is impracticable on any large scale. Plasma or serum, which, in dried form, will keep well in any climate, are the routine fluids of choice under battle conditions. Blood should be reserved for selected cases, as described below.

As a general rule, all transfusions should be begun with plasma or serum, and all of the order of three pints should be completed with it. Above three pints, and especially if exceeding five, a proportion of blood is desirable, but not essential. The ideal, if supplies are available, is probably one pint of blood to two of plasma. Lack of blood should never prohibit the pursuit of plasma transfusion to the full.

Blood is especially required for abdominal cases, for septic cases, for maintenance of condition during and after operation, for cases of massive hæmorrhage in whom equally massive plasma transfusion has reduced the oxygen carrying power below a tolerable level. Cases who have received large plasma transfusions in a forward area and who have subsequently deteriorated, fall into this last category ; secondary resuscitation almost always requires blood.

Volume and Rate.—Much of the criticism of the transfusion treatment of oligæmic shock has arisen from failure to appreciate that the volume required may be very large and that the rate of administration may need to be extremely rapid. Theoretically, the volume transfused should approach the volume lost, and this may be as much as seven or eight pints. If this can be done rapidly the result is remarkable, except in some cases of massive injury (*vide* infra). In the presence of circulatory failure, however, both the volume and the rate should be controlled by the response, as judged from serial observations of general condition and of the blood pressure. If the reading is below 80 mm., the rate should be rapid (one pint in seven to ten minutes). Transfusion should continue until the blood pressure rises to a normal level (110–120 mm.) and at the same time the rate be gradually slowed. When the blood pressure is in the region of 100 mm., signs of overloading of the right heart need to be watched for, though this is an unlikely complication.

When normal level has been reached, the transfusion should continue as a slow drip until the patient is taken to the operating theatre. Here, too, the drip should continue so that any sudden collapse due to vasodilation induced by anæsthesia, or to blood loss at operation may be immediately countered. It has to be borne in mind that certain individuals will not tolerate a fast rate even though such a rate is required. Intolerance to rate is shown by a rigor, which ceases as soon as the rate is slowed.

FACTORS INHIBITING OR PROHIBITING RESPONSE TO TRANSFUSION

General

A classical response to transfusion is a rise in blood pressure of 10–20 mm. for every pint transfused. Extensive and overwhelming injuries, continuing hæmorrhage (commonly an undetected internal hæmorrhage), inadequate volume, too slow a rate and delay in beginning treatment will all reduce the expected result. Thus the early phases of a delayed case may be disappointing and some may be found to have reached an irreversible state. Cases that have been revived once and who afterwards deteriorate are always more difficult to revive again. None of these features should lead to the abandonment of transfusion, but rather to its well-judged pursuit, supplemented by other aids such as cardiac stimulants when it is felt these are required. *Most cases of failure as well as so-called "delayed shock," that is, a recrudescence in a case successfully revived, are due to undetected internal hæmorrhage.*

Special Types of Injury

Massive injuries may inhibit response. The circulatory symptoms may be temporarily or partially abolished, yet the case may deteriorate or die from causes not fully understood but which are believed to be concerned with toxic substances derived from the damaged tissue. In such cases early operation is almost as important as blood volume restoration. *When adequate transfusion is apparently ineffective, operation should no longer be delayed as it offers the only chance of survival. Transfusion should continue during operation.*

Central nervous system injuries respond poorly to transfusion; little or no response may be anticipated with spinal cord injuries, whilst head injuries are hardly less satisfactory. In general, these cases should not be transfused unless injuries elsewhere are a complicating factor, and massive transfusion is usually harmful.

Thoracic injuries often respond badly, especially if there is mechanical interference with circulation. In certain types of thoracic injury transfusion is contraindicated (*vide* infra).

Abdominal injuries may fail to respond until the source of bleeding has been controlled.

Infected cases, such as those suffering from ischæmia and massive gas gangrene of a limb, or pneumonia, respond badly, as do patients with developing *fat embolism* or *acute dilatation of the stomach*.

CONTRAINDICATIONS TO TRANSFUSION

The primary indication for transfusion is blood volume reduction. Nevertheless, no harm is done by mistakenly transfusing a case, say, of neurogenic shock, which will often respond with extreme rapidity to quite a small transfusion, even though the primary indication is not present. Nevertheless, certain types of case are definitely made worse by transfusion, and these must be borne in mind. Obvious primary cases which should *not* be transfused are those suffering from *myocardial failure, toxic hypotension, coronary occlusion, mechanical causes such as hæmopericardium, pulmonary embolism and fat embolism,* and, frequently, those suffering from the *cerebral type* of shock.

The diagnosis of fat embolism is extremely difficult, but its likelihood should always be borne in mind in cases of fracture, and its occurrence should be considered in any injured person who develops pulmonary or cerebral symptoms without obvious cause. Transfusion definitely makes these cases worse.

Certain types of pulmonary damage also are a contraindication to transfusion. With *blast lung* transfusion increases alveolar hæmorrhage, and the condition should be thought of with the apparently lightly injured who do not readily respond to treatment, especially when a ruptured tympanic membrane is also present. Those who have been affected by *pulmonary irritant gases* (phosgene, carbon monoxide) should never be transfused, as the procedure merely increases the exudate.

SUPRARENAL CORTICAL EXTRACTS AND PRESSOR DRUGS

There is as yet no fully established evidence that suprarenal cortical extract has any place in the routine treatment of oligæmic shock. Likewise, many vasoconstrictor drugs—adrenaline, ephedrine, caffeine, pitressin and others, have been advocated with a view to supporting a declining blood pressure. Unfortunately, their action is to dam up the blood in the arterial system and to diminish the supply to the tissues. All that can be said is that they may have a beneficial action when combined with infusion of a crystalloid fluid (which temporarily restores blood volume) whilst making arrangements for a protein fluid transfusion. On the other hand, the pressor drugs with a reasonably sustained action have a definite place in the treatment of sudden collapse of neurogenic origin. Methedrine is the most suitable drug for this purpose and should be given in a dose of 30 mgm. intramuscularly or 15–30 mgm. intravenously.

BURNS

Burn shock arises from oligæmia caused by plasma exudation into the damaged tissues. It is consequently associated with hæmoconcentration which adds to the embarrassment of the circulation. The onset of shock is variable in time, but may be rapid; it is almost always to be expected in adults who have burns of 15 per cent. or more of the body surface. With burns to this extent, treatment for shock should be undertaken without delay in anticipation of symptoms. Since the oligæmia is due to plasma loss, the replacement fluid should be plasma. The treatment has to be *continuously* maintained for at least the first twenty-four hours, after which time the local fluid loss usually begins to subside, and the danger of oligæmic shock disappears. Whenever facilities are available, the volume and rate of the transfusion should be controlled by hæmatocrit and/or hæmoglobin estimations and/or serum protein determinations. Failure to overcome the oligæmia of burn shock is almost always due to inadequate administration or too slow a rate, matters which are very difficult to estimate without laboratory control. Formulæ for calculating the amount required according to the extent of the burn have been found to give a result far too low. Experience has shown that moderate burns (20–30 per cent. of body surface) may require as much as five to ten pints of plasma in the first twenty-four hours, whilst severe cases (30 per cent. or more) may need fifteen pints or more (in the early stages, at the rate of a pint an hour). Glucose saline is useful after the initial period, in order to overcome the dehydration induced by the vomiting, which is so common in the early phases.

When burns are associated with carbon monoxide poisoning, transfusion requires great judgment on account of the frequently associated pulmonary œdema caused by lung irritation.

CRUSH INJURIES

Men who have been trapped for an hour or more beneath debris should be considered as potential cases of crush syndrome, and hence likely to develop delayed and fatal renal failure. History is not always obtainable but the possibility of this type of injury should always be suspected in the presence of unexplained erythema, blisters, loss of sensation, paralysis or gross swelling of an otherwise uninjured part. Symptoms of shock arise from oligæmia due to plasma loss into the crushed tissue, but prophylactic treatment to avoid the delayed renal failure is a first priority measure ; it must be instituted without delay and if the general condition warrants it, even before the circulation to the injured part is restored. Plasma transfusion for the oligæmia will, as always, be regulated by general condition and blood pressure readings. To avoid renal complications, it is essential to maintain continuous alkalinity of the urine and a good urinary output, in order to ensure excretion of myohæmoglobin and other little-understood toxic metabolites which, with an acid urine, cause irreparable renal damage. Methods for alkalinization are described on pp. 46, 47. A measured fluid intake of at least six pints per day should be given either by mouth or by vein.

BLAST INJURIES

Severe blast may cause thoracic and abdominal lesions. Other multiple injuries are usually present, but these are not an essential part of the clinical picture. Diagnosis depends largely on an accurate history ; pain in the ear and ruptured drums are common. Anoxia dominates the early clinical picture. Breathing is rapid and shallow, or, slow and laboured. Efficient oxygen treatment and complete rest are essential ; venesection may be beneficial. Transfusion, general anæsthesia and exertion are contraindicated. Morphia should be used with care. Bacterial infection superimposed on blast lung is a danger and should be controlled by adequate chemotherapy.

DEHYDRATION

Dehydration implies deficiency of tissue fluid as distinct from fluid in circulation ; when severe it may also reduce the circulating fluid.

Some degree of dehydration is common in battle casualties. Factors which contribute to this are physical exertion with sweating, reduction in fluid intake by reason of rationing of water or lack of opportunity to drink, sweating or vomiting after injury, and, morphia administration, which may suppress the desire for fluid which normally ensues as the result of blood loss (p. 9). For example, in hot climates, a man may sweat 2–3 litres in 24 hours, and this is the equivalent of 1–3·7 g. NaCl per litre. Similar losses of fluid, of sodium and of chloride may accompany severe vomiting. The great importance of administering plentiful simple drinks, containing salt, to all wounded men (with certain exceptions) has already been emphasized (p. 8).

Physiology of Water Balance

The body water is divisible into the *intracellular* (50 per cent. of body weight) and the *extracellular* (15–20 per cent. of body weight). The extracellular is again divisible into the *interstitial* (12 per cent. body weight) and the *plasma* (6 per cent. body weight). Balance is maintained mainly by the osmotic pressure exerted by plasma protein (especially albumen) and electrolyte (particularly the sodium ion). Normal water balance is therefore disturbed when losses of water and electrolyte are in excess of fluid and salt intake, and when plasma protein is reduced. This last fact is frequently neglected when fluids are prescribed. The normal daily intake of the body amounts to some 3 litres of water and 10–20 g. sodium chloride ; this covers the fluid and salt lost in the expired air, sweat, secretions, fæces and urine. *The best clinical index of a good water balance is a daily output of* 1½ *litres of urine with a S.G. of approximately* 1·015.

Clinical Signs and Symptoms of Dehydration

When losses of water and electrolyte are excessive the urinary output suffers a compensatory reduction in order to conserve the normal level of tissue water as long as possible. Consequently there is insufficient water for the renal excretion of solids, and nitrogenous wastes begin to accumulate in the blood stream. When the loss amounts to some 7–10 pints, the overt signs of dehydration appear, namely, thirst, weakness and a hot inelastic skin. By this time renal function has already been depressed, so that the blood non-protein nitrogen is above the normal level.

Accompanying this renal dysfunction there may be damage to the parenchyma of the kidney, which is manifested by the appearance of red blood cells and casts in the scanty urine. This evidence of damage may persist for some days after the beginning of treatment, and must always be borne in mind, especially when giving crystalloid fluids by vein to severely dehydrated casualties.

Circulatory failure occurs when the water and electrolyte deficit amounts to 12–16 pints. Thereupon, the blood pressure falls, the pulse becomes rapid and thin, and cyanosis indicates the presence of hæmoconcentration. The clinical picture at this stage closely resembles that of oligæmic shock. Death is sometimes preceded by a low muttering delirium.

Diagnosis.—In the wounded man the symptoms and signs of dehydration, the earliest of which are thirst and weakness, followed by a desiccated sunken appearance of the face, leathery tongue, inelastic skin and scanty urine, are usually partly or completely masked by those caused by the injuries themselves. Much practice and careful evaluation of the history, especially of the conditions preceding and following the actual wounding, are necessary if the correct emphasis is to be given to the effects of dehydration, as distinct from those of the injury. If the medical officer will always consider the possibility of dehydration, he will have gone far towards prescribing the best treatment.

Treatment.—The object of treatment is to replace lost tissue fluid. Fluid and electrolyte may be administered by the oral, rectal and intravenous routes.

Oral Route.—Simplicity makes this route the best of the three for the treatment of the mild or moderate case of dehydration ; it can be used in all cases, save in the unconscious and in those with abdominal wounds, or some injury which makes drinking impossible (p. 8).

Rectal Route.—For those in whom the oral route is contraindicated, the administration of fluid per rectum has two attractive advantages over the intravenous route ; neither sterile equipment nor sterile fluids are required. Tap water, if available, is satisfactory. Prepared solutions should be used at half normal strength ; of these 0·425 per cent. sodium chloride solution is the fluid of choice. The disadvantages of the method are : absorption from the rectum is uncertain ; some patients find the method uncomfortable, or cannot tolerate the presence of a tube or fluid in the rectum ; peristalsis may be stimulated and encourage the spread of a localized peritoneal infection ; occasionally the development of paralytic ileus is favoured. Fluid can be given as a continuous drip at a rate of 30–50 drops/min. The total fluid which can be given by this route in 24 hours amounts to about 2 litres.

Intravenous Route.—In all severe cases, and in others when neither the oral nor the rectal routes can be used, the water deficit has to be made up by crystalloid solutions given intravenously.

The administration of large quantities of crystalloid solutions by this route is a procedure not to be undertaken in a light-hearted manner. Fluid intake and output must be carefully recorded. Constant watch must be kept for the premonitory signs of œdema, and an attempt should be made at the outset to assess the condition of the heart and kidneys, as well as the nutritional state. Reduced cardiac or renal function, hypoproteinæmia, and especially pulmonary damage, indicate that intravenous infusions must be given with the greatest care. Renal impairment resulting from trauma must always be borne in mind. Failure to consider these factors may lead to the attribution of œdema, developing during infusion, to the composition of the crystalloid solution, instead of to its correct cause. *All who have bled or whose blood volume has been reduced in other ways, should first receive protein fluid intravenously to restore plasma protein to its normal level before crystalloid solutions are given.*

Choice of Fluids (*see also* p. 41).—The following isotonic solutions may be used : 0·85 per cent. sodium chloride solution, 5·0 per cent. glucose solution, or an isotonic mixture of glucose and saline. Hypertonic solutions have no advantage, save perhaps in cases of cerebral œdema. Hydration with physiological saline alone entails the danger of producing œdema from excess of sodium chloride, except in those cases who have lost very large amounts of salt. It is better to alternate a pint of physiological saline with a pint of 5 per cent. glucose or, in cases where renal impairment is suspected, to give 2 pints of glucose to 1 of saline. For convenience, the two solutions may be mixed and dispensed as one isotonic solution in the above proportions. The equivalent of alternate bottles contains 0·425 per cent. NaCl and 2·5 per cent. glucose (13·75 g. NaCl per 3 litres ; ordinary daily requirement) ; the equivalent of one bottle of saline in three contains 0·3 per cent. NaCl and 3·3 per cent. glucose (9 g. NaCl per 3 litres). Owing to the frequency of renal impairment in the injured, the latter strength is the more favoured for battle conditions, on account of its lower chloride content.

Rate of Administration.—Crystalloid solutions should be given slowly. In severely dehydrated cases, 500 c.cm. may be given in 2 hours, but for general purposes 500 c.cm. in 4 hours suffices (40 drops per minute).

Volume of Fluid.—In addition to the normal daily water requirements of the body, 3,000 c.cm. (1,500 c.cm. for urine and 1,500 c.cm. for loss through skin and lungs), an attempt must be made to replace the water deficit, which, in the case of dehydration, uncomplicated by wounds, may be gauged by the symptoms and signs described above. Unfortunately, in practice, the clinical picture is usually complex, and the urinary volume then becomes the only effective guide to adequate hydration. If a man passes at least 1,500 c.cm. of urine daily, with a specific gravity of 1.015, his fluid intake is sufficient.

Abdominal Cases.—The greatest users of crystalloid fluids given by the intravenous route are abdominal cases in whom post-operative gastric suction (p. 62) is being employed. Slow intravenous infusion of fluid may be required for periods up to seven days to replace not only the gastric and intestinal secretions withdrawn by tube, as well as those trapped in distended paralytic loops of bowel, but also to supply the normal daily water requirements of the body (3,000 c.cm.) since fluids per os are excluded.

Because of the prolonged intravenous therapy with its attendant danger of œdema, constant careful clinical supervision is essential. With normal renal and cardiac functions, and a normal plasma protein level, it is unlikely that the steady infusion of glucose-saline will supply an excess of sodium chloride. The danger may be avoided with certainty by replacing the volume of secretions drained from the gastro-intestinal tract (NaCl content, approximately 1 per cent.) by an equivalent amount of physiological saline, and by supplying the other fluid requirements in the form of 5 per cent. glucose solution. In practice either of the isotonic saline-glucose mixtures described above are suitable for combining these requirements. The solution containing 0·3 per cent. NaCl and 3·3 per cent. glucose is well within the margin of safety. The prolonged post-operative abdominal case in whom the protein intake is necessarily greatly reduced or negligible, may suffer a significant fall in plasma protein. As such a fall develops, so the likelihood of œdema accompanying intravenous crystalloid therapy increases. Consideration should always be given to the possible value of replacing several bottles of glucose-saline by plasma in the later stages of treatment.

ADVANTAGES OF A RESUSCITATION WARD

The admission of large numbers of casualties into any hospital calls for a ward where shocked patients may be quickly and skilfully attended. Routine work in permanent hospitals often makes it impossible to set aside a special ward in waiting, but all hospitals should have chosen such a site, have assembled all the necessary equipment and have appointed a staff who are fully conversant with the work that has to be done. Under active service conditions the majority of resuscitation work takes place at Field Dressing Station level and here the organization should be highly developed. In urgent cases the work has to begin in a Field Ambulance. A scheme for the general administration of a resuscitation ward is given below.

A properly equipped and staffed resuscitation ward ensures that all patients requiring urgent treatment receive it with the minimum of delay and in the best surroundings.

The reasons for this are :—

1. From the moment of the patient's arrival in the ward, the staff know what to do and how to go about it.

2. There is no delay in obtaining apparatus, as it is all in the ward.

3. Heating systems may fail. Emergency measures can seldom embrace several wards at once, but it is simple to heat one ward and to have means for rapidly warming the very cold patients.

4. Response to treatment can be more acutely observed ; this may enable life-saving measures to be adopted at the right time.

5. It allows a proper control over the arrangements for giving intravenous fluids. The whole system of resuscitation depends on close co-operation between those in charge of blood and other supplies of transfusion fluids and those administering them. There are times when it is difficult to obtain such fluids, and a knowledge of all the working arrangements of the system is essential for the medical officer in charge of the ward, to ensure maximum benefit for the largest number of cases.

RESUSCITATION WARD

Size

Experience shows that approximately 15 per cent. of casualties require resuscitation treatment. The ward selected should therefore be of such a size as to accommodate this proportion of the total number of casualties which could on any one occasion be admitted to the hospital. Hospitals which are especially likely to receive air-raid casualties should make a somewhat more generous allotment of space, because many who are brought quickly from the scene of a raid are still suffering from neurogenic shock. Such patients should be admitted to the resuscitation ward for treatment with simple measures. Neurogenic shock can then be clearly differentiated from oligæmic shock, and those who drift into the latter condition can be treated without delay.

Site

The ward should be large, solidly built, easily heated, devoid of draughts, quiet and near to both the reception department and the operating theatre. When these last two conditions cannot be satisfied it is preferable to site the ward near the operating theatre, as patients have usually to be followed into the theatre with a transfusion in progress. The windows should be bricked up ; work in the ward will not then be disturbed by the shattering of windows nor rendered difficult by cold. Ventilation according to local facilities and conditions must be provided. Emergency lighting and heating should be arranged, in case of failure of central sources.

Lay-out

In permanent hospitals a ward, holding twenty or more beds, should be equipped with trolley-screens. It is inadvisable to move the severely injured more than is necessary ; most cases do best if the only move is from the stretcher to the operating table. The ward should not, therefore, be filled to capacity with beds. Ample room should be left for stretchers on the floor and on trestles. Beds should be prepared with a loose canvas cover, a mackintosh sheet and a blanket ; hot-water bottles can be placed beneath the blanket ; top blankets should be obtained, when needed, from a hot-air cupboard ; sheets are undesirable. If necessary the patient can be lifted on to a trolley by means of the canvas cover. Many wards have a single-bedded room nearby, which should be fitted with a table, good light, facilities for scrubbing and the means for giving a general anæsthetic. Such a room is useful for the bleeding of donors and for the treatment of special cases. If a room is not available, then a portion of the ward should be screened off for these

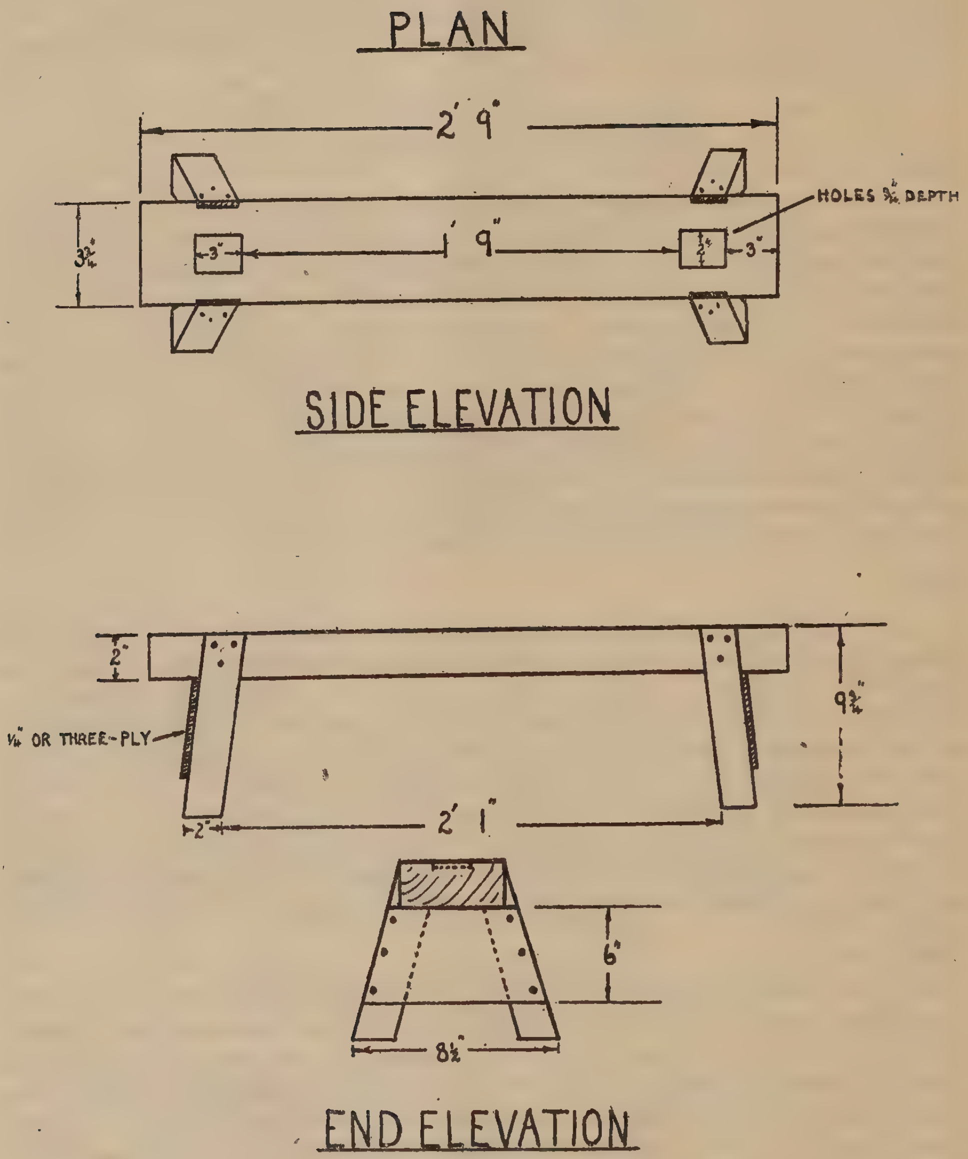


Fig. 1.

Stretcher trestle-block.

purposes. With units on active service provision must be made for treatment of cases upon stretchers. Trestles should be placed to receive the stretchers in the places ordinarily occupied by beds, but a certain amount of floor space should be left for the reception of stretchers at floor level. Trestles should be made in two sizes, one having legs five inches higher than the other in order to allow the patient to be tilted head downwards. The two sizes of trestle should be clearly marked to distinguish one from the other. For stretchers on the ground, trestle-blocks with slots to receive the runners are extremely useful (Fig. 1).

Personnel

The *resuscitation officer* must be given full control of the patients in the ward and his advice should be accepted by the surgical teams, with whom he must collaborate closely. It is therefore essential that he be a medical officer of some experience, preferably a physician. Selection of cases for treatment in the ward will vary according to the unit. Whatever arrangement be in force, the resuscitation officer must maintain close liaison with the reception officer, who should also be an experienced medical officer, since he will decide which patients are to be admitted to the resuscitation ward. An understudy is always advisable and he should be available to assist during peak periods. The resuscitation officer and his understudy should be fully conversant with the treatment of gas casualties.

The O.C the Field Transfusion Unit is naturally the Resuscitation Officer of the unit to which he is attached. He should depute and train understudies from among the general duty medical officers of the unit, to be ready to assist him or take his place.

Nurses or orderlies should be allotted in the proportion of one per four beds. In a Field Transfusion Unit the two orderlies form the nucleus of the resuscitation ward staff, but other general duty orderlies should be trained in this work and be available as supplements.

TRAINING OF NURSES AND ORDERLIES

The resuscitation officer is responsible for training the staff to a high state of efficiency, so that all understand the main essentials of the work and are fully conversant with the general arrangements of the ward.

Instruction should be given on the following matters :—

(1) The immediate care of the wounded on admission, including the systematic recording of all facts of importance to the resuscitation officer (p. 23).

(2) The preparation of a patient for transfusion, including immobilization of a transfusion limb (p. 56) and the setting up of a travelling transfusion (p. 60).

(3) Care and maintenance of all equipment in the ward in a state of readiness, especially the cleaning, reconstruction and sterilization of all apparatus for giving intravenous fluids, including blood (p. 48).

(4) *Stored Blood.*—Survival period and recognition of hæmolysis; criteria of fitness for use; storage conditions; warming of blood before use (pp. 36, 42, 43).

(5) *Plasma.*—The keeping properties and storage conditions of plasma; criteria of fitness for use, such as presence of clots and turbidity (p. 40).

(6) *Dried Plasma and Serum.*—Keeping properties; reconstitution and administration (p. 41).

(7) *Crystalloid Solutions.*—Administration (pp. 16, 41, 42).

(8) The duties of an assistant at a transfusion; assembly and preparation of all necessary apparatus and instruments, control of rate of flow, removal of needle or cannula and after-care of limb.

(9) The recognition and treatment of a mis-matched transfusion and other less serious reactions (pp. 44, 46).

(10) The determination of blood pressure and pulse rate. Distinction between volume and frequency of pulse.

(11) The use of surgical instruments, oxygen cylinders and masks, sedative and stimulating drugs, bed-blocks, trestle-blocks (Fig. 1) and stretcher trestles.

(12) The special procedures or observations necessary on the admission of a patient, *e.g.* chest and head injuries not to be placed in the head low position until seen by an officer; clothing to be cut off with the minimum of manipulation of injured parts; observation of the amount of bleeding; the uses and dangers of the tourniquet (p. 56); application of warmth (pp. 9, 27); administration of warm, sweet drinks (tea, coffee, lemonade) to all conscious patients not suffering from penetrating abdominal wounds or head injuries (p. 8).

For active service units a knowledge of the care and maintenance of a refrigerator is also essential.

The exact procedure in a resuscitation ward will be evolved according to the ideas of the resuscitation officer, but arrangements or rules made must be efficiently taught to the staff, so that they can carry them out rapidly and efficiently without close supervision.

During the instruction courses frequent " drills " should be held in which an increasing number of wounded patients are admitted to the ward. In this way the staff will become familiar with their duties and thoroughly proficient. Drills should be arranged in which the ward is dismantled and set up, so that the staff may learn the necessity of the careful setting out of apparatus and that each piece has an allotted position. When proficiency in both these drills has been acquired they may be combined in one exercise, the ward being first set up, and this being followed by the admittance of a series of dummy casualties. Drills under conditions of emergency lighting, and when wearing protective clothing and respirators, are also valuable.

GENERAL DUTIES OF A RESUSCITATION OFFICER

The resuscitation officer should grade the patients admitted into various categories according to the degree of their injuries as well as their urgency or fitness for operation. The following scheme is given as an example :—

Category	*Classification*
Head wounds, penetrating chest and abdominal wounds	xxx
Compound fractures and multiple gun-shot wounds	xx
Isolated limb injuries	x

A chart should be kept, showing time of admission, nature of injuries, classification sign and a space for inserting the letter O when the patient is considered fit for operation. Each patient may be given a number against his name, which should be prominently displayed on his chart and also inserted on the coloured label which should be tied to him when receiving treatment in a resuscitation ward. When the patient is transferred to another part of the hospital this label should be attached to his bed, so that the resuscitation officer may follow up his cases without delay.

It is a good arrangement for the surgeon of each surgical unit to visit the resuscitation ward at least once in four hours. He should be shown the classification charts, which will allow him to choose his cases to the best advantage. Time is also saved by visiting only those whom the resuscitation officer has marked as fit for operation. If casualties are very numerous this method of orderly selection may not be possible, and in these circumstances the surgeon and resuscitation officer should make their selection together.

Once agreement has been reached as to the order and number of cases to be operated upon, every effort must be made to ensure a continuity of operations. The resuscitation officer should set up all transfusions himself unless he knows that an assistant is an adept at this procedure. Inexpert help in this respect wastes more of the officer's time than if he had himself carried out the procedure from the outset.

GENERAL DUTIES OF NURSING STAFF

In preparation for the reception of casualties the ward should be set out and a plentiful supply of warm blankets prepared in advance.

The nurse or orderly admitting a case should immediately inquire whether the patient has a chest or head injury. If the bearers do not know, the stretcher should be placed on the floor pending examination of the patient's card or his examination by the resuscitation officer. Cases of chest and head injuries, as well as cases of severe shock without visible signs of injury, should be left lying flat until examined by the officer. All others should, as a routine, be placed in the head low position either in beds or on stretchers with the foot raised by blocks, or on trestles or, if stretchers on the floor, on trestle-blocks (Fig. 1). Restless patients should not be put on trestles. Movement is to be discouraged. Common sense and experience will dictate which can be moved from stretcher to bed and which are better left undisturbed. An injured limb should not be moved unless the need is urgent. A tourniquet should be looked for, but must on no account be removed without the sanction of the officer ; nor should a tourniquet be applied without good reason. If known, the time at which a tourniquet was applied should be recorded on the patient's chart, and a note made of the amount of blood on a stretcher, a watch being kept to see that this does not increase to a dangerous extent. Morphine has almost always been administered to casualties before admission to a resuscitation ward, the record card being marked with the dose and time (or sometimes the patient's forehead). When no morphine has been administered, or when the time interval exceeds four hours, a syringe should be loaded with a dose to be given at the time of the officer's examination or at his direction. Having completed these preliminary examinations no time should be lost in removing the clothing and getting the patient covered with warm blankets supplemented by whatever warming arrangements are available (p. 27). When clothing cannot be removed without causing pain or undesirable movement it should be slit at the seams with a strong pair of scissors (carpet-fitter or paper-hanger type). Stretcher cases should have the blankets folded and wrapped according to R.A.M.C. Training Pamphlet No. 1 (1943). This method, in principle, ensures that the patient has sufficient protection underneath as well as on top and allows of free access for examination. Note must be made of the rate and volume of the pulse. Quite often the rate can only be determined by using a stethoscope and counting the apex beat. If the patient has an uninjured arm the clothing should be slipped off or cut off and a sphygmomanometer cuff applied. The instrument itself can then be plugged in and the blood pressure recorded by the officer or some other person delegated by him. Spare cuffs greatly facilitate this important side of resuscitation work and reduce the amount of disturbance to the patient. If the patient is conscious, and not suffering from abdominal wounds or head injuries, he should be encouraged to take warm drinks. Large gaping wounds should have gauze soaked in acriflavine applied to them. Wounds must not be bandaged until seen by the officer. Those in charge of patients should make it their business to see that the resuscitation officer examines the case with the minimum of delay and that all relevant points elicited by him are properly recorded.

When a transfusion is ordered all the apparatus should be immediately collected. Conscious patients should be sympathetically told what is going to be done, with emphasis on the necessity for keeping the arm still. The arm should be fully extended, with a support under the wrist and the hand kept covered and warm. Restless patients need to have the arm held in a splint (p. 56). During the transfusion the attendant is responsible for seeing that the fluid runs in at the proper rate. The volume and rate of the pulse should be recorded every fifteen minutes, and the resuscitation officer informed of any deterioration in the patient's general condition. When the transfusion is complete the apparatus should be screwed off and the officer informed, so that he may judge whether more should be given or whether other treatment is required. A patient sent to the theatre with a transfusion in progress should be accompanied by an attendant. The attendant must be conversant with the signs and symptoms of mis-matched transfusion and other less serious transfusion reactions (pp. 44, 45). A mis-matched transfusion should be stopped immediately and a report made to the officer.

EQUIPMENT

The equipment of a fixed hospital is obviously more elaborate than that of a Field Transfusion Unit on active service, but the lists set out below provide a choice according to local facilities and supplies. It is essential to assemble all small equipment, drugs, etc., in cupboards so that all the staff know where everything is kept. Every hospital should allot a room where donors can be bled and where all the apparatus required for the bleeding (pp. 36, 42) should be kept.

1. Intravenous Fluids

Stocks of protein-containing intravenous fluids (blood, plasma, serum) should be based on an estimate that each case may require one to one and a half litres for efficient treatment. Stocks of durable fluids (plasma, serum) or dried products should not be depleted for isolated cases. A blood donor should be procured as in ordinary peace-time conditions. A stock of isotonic glucose-saline (p. 41), estimated at one litre for each case, should also be kept. This is mainly required for the intravenous hydration of abdominal cases.

2. Equipment for Administering Intravenous Fluids

Each bottle of protein-containing intravenous fluid should be accompanied by a separate packet containing the sterilized equipment for administration to the extent of one set for each two 540-c.cm. bottles. Glucose-saline stocks should be equipped with one set for four 540-c.cm. bottles.

Stands from which transfusion bottles can be suspended to the extent of 25 per cent. of beds are essential unless the beds are already provided with a suitable bracket. Fig. 2 illustrates three types of suitable stands.

Facilities for warming blood should be arranged. On active service this is done in a bucket of warm water.

In appropriate units the equipment should be supplemented with :—

(*a*) Apparatus for rectal saline administration—two or three sets.
(*b*) Apparatus for continuous gastric suction (p. 62)—two or three sets.
(*c*) Equipment for the taking of blood (p. 42).
(*d*) Apparatus for administration of fluid by stomach drip.

3. General Equipment

Trolley-screens, bed-blocks, stretcher trestles (of two sizes, so that the head is five inches below the feet, stretcher trestle-blocks (Fig. 1) ; the standard trestle can be modified for this purpose by

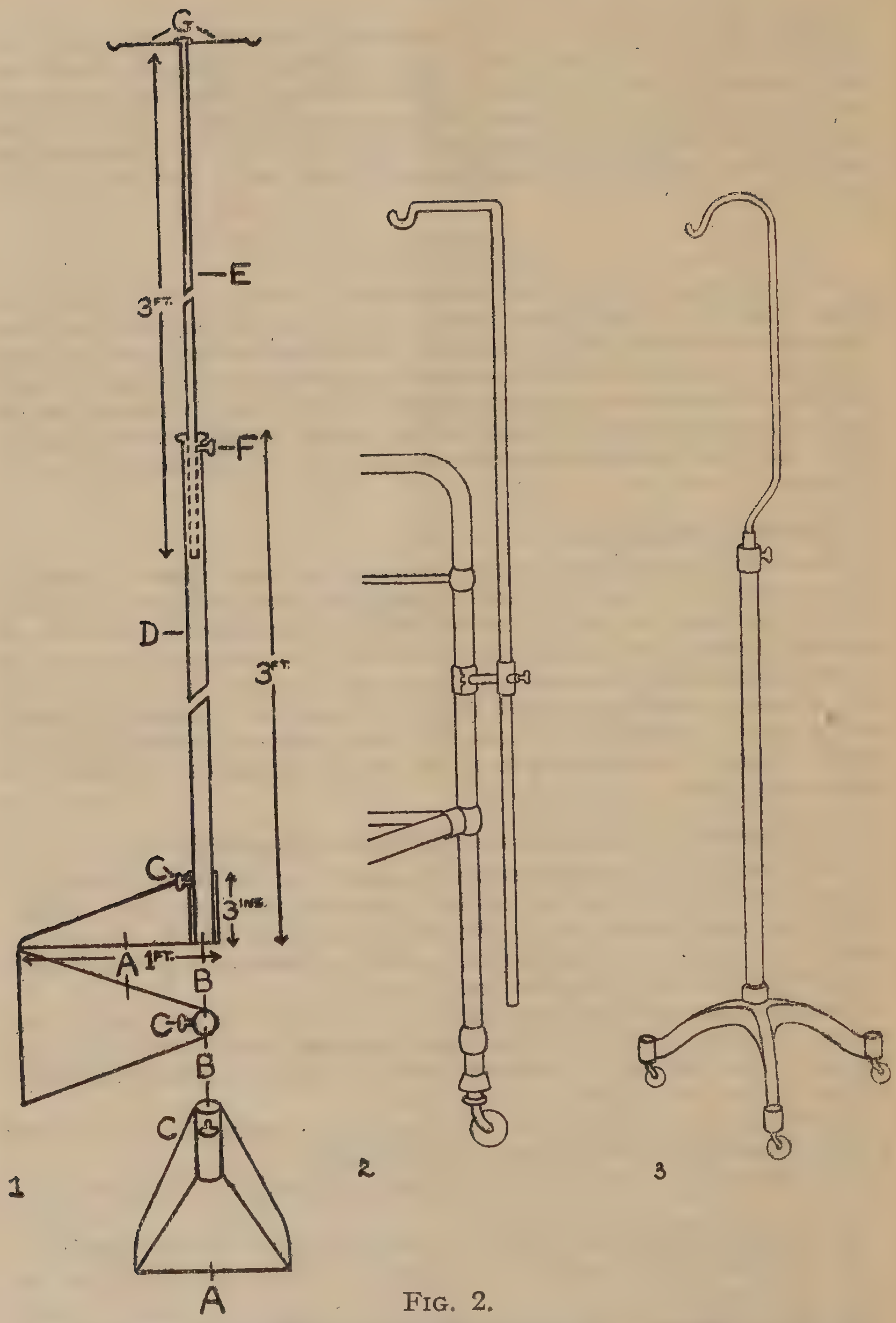


FIG. 2.

Various stands suitable for transfusion work. (1) Standard army telescopic stand issued to Field Transfusion Units (A—foot-plate; B—socket for receiving first section; C—clamping screw; D—first section; F—clamping screw; E—second section; G—double hook).
(2) Bed pattern (Chas. F. Thackray, Ltd.). (3) Movable ward pattern (John Bell and Croyden).

moving up a lower cross-bar to a position about 8 inches below the trestle top. Lighting apparatus, to include head lamps and hurricane lamps. Back rests (approximately ten per cent. of beds), limb splints, mackintosh sheeting, catheters, urinals and bedpans. Small sterilizers or small saucepans (8 in. × 4 in. deep) with sieves, complete with lids, for the boiling of small instruments. Well-equipped hospitals may provide themselves with large containers for drinks, to be suspended above each bed, from which the fluid is fed to the patient by a rubber tube with an end piece that can be changed. Large kettles for the making of warm drinks should be available, also a number of Primus stoves in case of failure of gas or power.

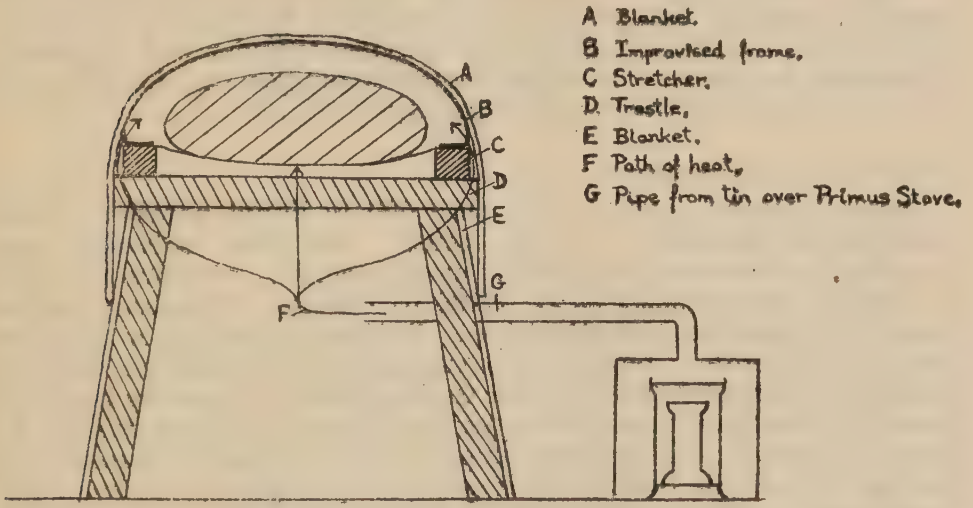


FIG. 3.

Warming apparatus made with a Primus stove.

Facilities for warming patients are necessary under cold conditions (p. 9). These range from improvisations with a Primus stove, as described in R.A.M.C. Training (1935), Section 231 (Fig. 3), to electric cradles and elaborate thermostatically-controlled electric blankets (these last need to be most cautiously employed, p. 9). Whatever resources are available, there should always be a generous supply of hot-water bottles as well. Oil stoves as an emergency stand-by are valuable for heating the ward.

4. Surgical Equipment

Simple instruments for cutting down on a vein ; instruments for arresting hæmorrhage, including tourniquets ; instruments for the immediate closure of thoracic wounds, together with a plentiful supply of ligatures, bandages, gauze, dressings, elastic plaster, zinc oxide plaster, bowls, receivers and syringes (2 c.cm. and 5 c.cm.) with fine needles. This, and much of the medical equipment, should be assembled in complete sets and then distributed on trolleys. Each attendant should be equipped with a pair of carpet-fitter's scissors (or scissors, stretcher bearer) for the cutting of clothing. A list of equipment carried by a Field Transfusion Unit on active service is given below. Here the equipment is disposed in a special box with divisions and trays (Fig. 5) movable from stretcher to stretcher; the box takes the place of a trolley.

5. Medical Equipment

Clinical thermometers, Higginson's syringes (for the exerting of positive pressure when administering intravenous fluids); sphygmomanometers, with a plentiful supply of spare cuffs; Ryle's duodenal tube.

B.L.B. masks (Fig. 12) for the administration of oxygen are an essential piece of equipment, together with flowmeters, reducing valves, cylinder pressure gauges and oxygen cylinder with keys and containers for same. In large hospitals oxygen can be piped to each bed from a central source of supply.

6. Drugs and Comforts

Surgical spirit; acriflavine 1 in 1,000 in liquid paraffin; local anæsthetics—procaine two per cent.; morphine solution conveniently in rubber-capped bottles gr. $\frac{1}{6}$ to ♏.vii.; atropine sulphate in solution conveniently as gr. 1/100 to 1 c.cm.; adrenalin; nikethamide (coramine); methedrine; Dettol-type or other suitable surgical antiseptic; tetanus and gas-gangrene antitoxin; sodium bicarbonate solution (one drachm to the pint) for irrigating burns of the eyes; atropine ointment one per cent.; ointment, anti-gas No. **3**; bleach ointment; one per cent. copper sulphate and other requisites for the immediate treatment of gas and phosphorus burns; sulphanilamide tablets for use, at the discretion of the officer, for the oral prophylaxis of wound infections; alkaline solutions for the treatmen of mis-matched transfusions (p. 46).

Brandy, tea, coffee, lemonade, bovril, marmite (sugar and salt to be added to all drinks).

7. Field Transfusion Unit

The following list shows the surgical, medical, drug and genera equipment carried by a Field Transfusion Unit on active service. The list of instruments may be accepted as the minimum required for resuscitation work on organized lines. An almost similar box of equipment is issued to Airborne Units (A.M.S. Form 11 A).

Section I (A)

Acriflavine, 0·1 per cent., in liquid paraffin, 4-oz. bottles	no.	1
Aqua destillata, 4-oz. bottles, rubber-capped, sterile ..	no.	1
Atropine sulphate solution, 1/100 gr. in 1 c.cm., in 2-oz. bottles	no.	1
Isotonic glucose-saline, in pint bottles	no.	100
Methedrine, boxes of 6 ampoules	ampoules	30
Morphine injection, 1½ oz. in 2-oz. amber-glass bottles	no.	2
Nikethamide, 2 c.cm. ampoules, in boxes of 6 ampoules	ampoules	24
Procaine and adrenaline (self-sterilizing) 3 per cent. solution in 2-oz. bottles	no.	2

Section I (B)

Plasma, dried with isotonic glucose-saline for reconstitution and with giving sets, in bottles	bottles	200
Serum, dried, Grouping, ampoules 1 c.cm.	prs.	10

Section II

Tablets, sulphanilamide, 0·5 g.	no.	50

Section III

Bandages, elastic plaster, 1 in. × 3 yds.	no.	1
,, open wove, bleached, 3 in. × 4 yds.	no.	10
Gauze, absorbent, bleached, 6-yd. packets	pkts.	1
Lint, cotton, absorbent, 4-oz. packets	pkts.	2
Wool, cotton, absorbent, 4-oz. packets	pkts.	2

Section IV

Jaconet, 36 in. wide	yd.	1

Section V (A)

Apparatus, oxygen, B.L.B., Field Pattern, complete	no.	2
Basins, dressing, enamelled iron, kidney-shaped, 6-in.	no.	2
Bowls, dressing, enamelled iron, round, 8-in.	no.	2
Catgut, sterilized, 20-day, size O	tubes	12
Cylinders, oxygen, full 40 cu. ft.	no.	2
Enemas, india-rubber, with vulcanite nozzle, complete	no.	2
Needles, suture, blunt point, straight, 1½-in.	no.	2
,, ,, curved, 1½-in.	no.	1
Plaster, adhesive, zinc oxide, 1 in. × 10 yds.	spools	2
Silk, suture, No. 2	oz.	2
Stands, Blood Transfusion, adjustable	no.	6
,, Transfusion, stretcher, wooden	no.	4
Stones, needle sharpening	no.	1
Tourniquet, Samway's, Max Page modification	no.	2

Splints and Appliances for Making

Pliers, wire cutting, for Cramer splinting	no.	1
Splinting, wire, Cramer, 60 cm. × 8 cm.	pieces	3

Section VI

Forceps, artery, Halstead, fine, curved, 5-in.	no.	2
,, ,, Spencer Wells, 5-in.	no.	2
,, dissecting, fine points, 5-in.	no.	1
,, ,, toothed, 5-in. (fine, 2/1)	no.	1
Giving sets, for glucose-saline, complete	no.	50

Each set consisting of :—

I.R. bung with 2 glass tubes, drip indicator, air filter, intravenous needle and adaptor, screw clamp and necessary I.R. tubing.

Knives, Bard Parker type, handles for, size 4	no.	2
,, ,, ,, blades for, No. 20	no.	6

Lamp, head, electric, "Ever Ready," with condenser, complete	no.	1
Lamp, head, electric, batteries for	no.	1
,, ,, ,, lamps for	no.	1
Needles, aneurism, curved, small	no.	1
Scissors for blood transfusion, blunt-pointed, fine	no.	1
Sphygmomanometer, complete in case, with canvas cover	no.	1
Ditto, armlets for, with 2 female adaptors	no.	2
Ditto, bellows for, with female adaptors and slow-release valve for	no.	2
Sterilizer, fish kettle, pannier pattern, complete with lamp	no.	1
Syringe, hypodermic, 2-c.cm , needles for	no.	12
,, serum, "Record," 2-c.cm. with four steel needles, in case, complete	no.	2
Apparatus, Transfusion and Infusion, Hospital Pattern	boxes	1
Bottles, dispensing, plain, screw-cap, 4-oz., containing solution of sodium citrate, 3 per cent. 100 c.cm.	no.	50

Section XI (A)

Crates, wire, to hold 10 bottles	no.	10

Section XIII

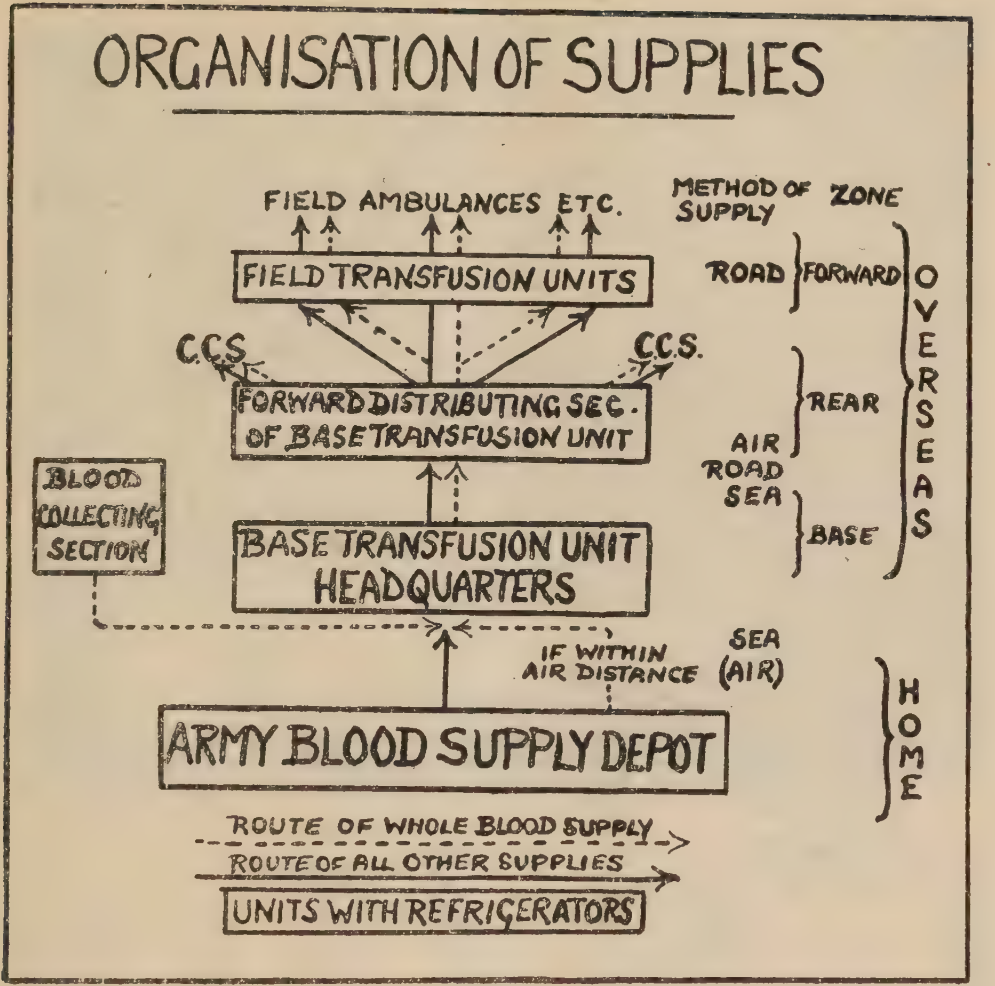
Box, wooden, 76 × 12 × 12½ in.	no.	1
,, tin, 8 × 3 × 1 in. for swabs (A.B.S.D.)	no.	4
,, ,, 11 × 4 × 4 in. (A.B.S.D.)	no.	4

ORGANIZATION, SUPPLIES, AND COMMUNICATIONS

The Army Transfusion Service is controlled by the Directorate of Pathology, War Office, through D.Ds.P. of Overseas Forces and A.Ds.P. of Home Commands. The separate units of the Service are Army Blood Supply Depot (Home), Base Transfusion Units (Overseas), Field Transfusion Units (Home and Overseas), whilst the general scheme of supply is shown in the diagram on page 31.

Army Blood Supply Depot (Home)

This large central organization is intended to supply, through Base Transfusion Units (Overseas) and Field Transfusion Units (Home and Overseas), the whole army, at home and abroad, with all equipment, with grouping serum and with all transfusion fluids that cannot be obtained locally. Plasma and serum, fluid or dried, are always obtained from this source. At home, blood is supplied to R.A.M.C. units within road delivery distance of the depot if they are unable to obtain blood by means of their own local organization, whilst crystalloids are supplied to units which have no facilities for preparing their own. The main functions of the depot are to ensure adequate supplies of assembled equipment, blood substitutes and crystalloid solutions to all Overseas Forces and to provide a service of stored blood when the theatre of operations is within air delivery distance. The depot is also the training school for resuscitation work and carries a staff of skilled engineers for the repair and servicing of all army refrigeration apparatus.



Base Transfusion Unit (Overseas)

One Base Transfusion Unit is provided for each Overseas Force with a personnel appropriate to the size of the Force. According to distance, this base unit is either largely self-supporting or obtains most of its supplies by air or sea transport from Army Blood Supply Depot (Home). The unit has facilities for the preparation of simple intravenous fluids, such as glucose-saline, and it carries a staff of engineers for refrigerator-servicing and repair. The main function of the base unit is to maintain supplies at forward units. The unit consists of a headquarters stationed at Base and one or more Forward Distributing Sections usually known as Advanced Blood Banks which service and supply Field Transfusion and other medical units in convenient sectors. The Advanced Blood Bank is usually sited at the most forward Air Transport Landing Ground (*see* Fig. 4). When required, the headquarters may have one or more Blood Collecting Sections for the establishment of a local service of stored blood as well as a Plasma Processing Section for the local preparation of plasma.

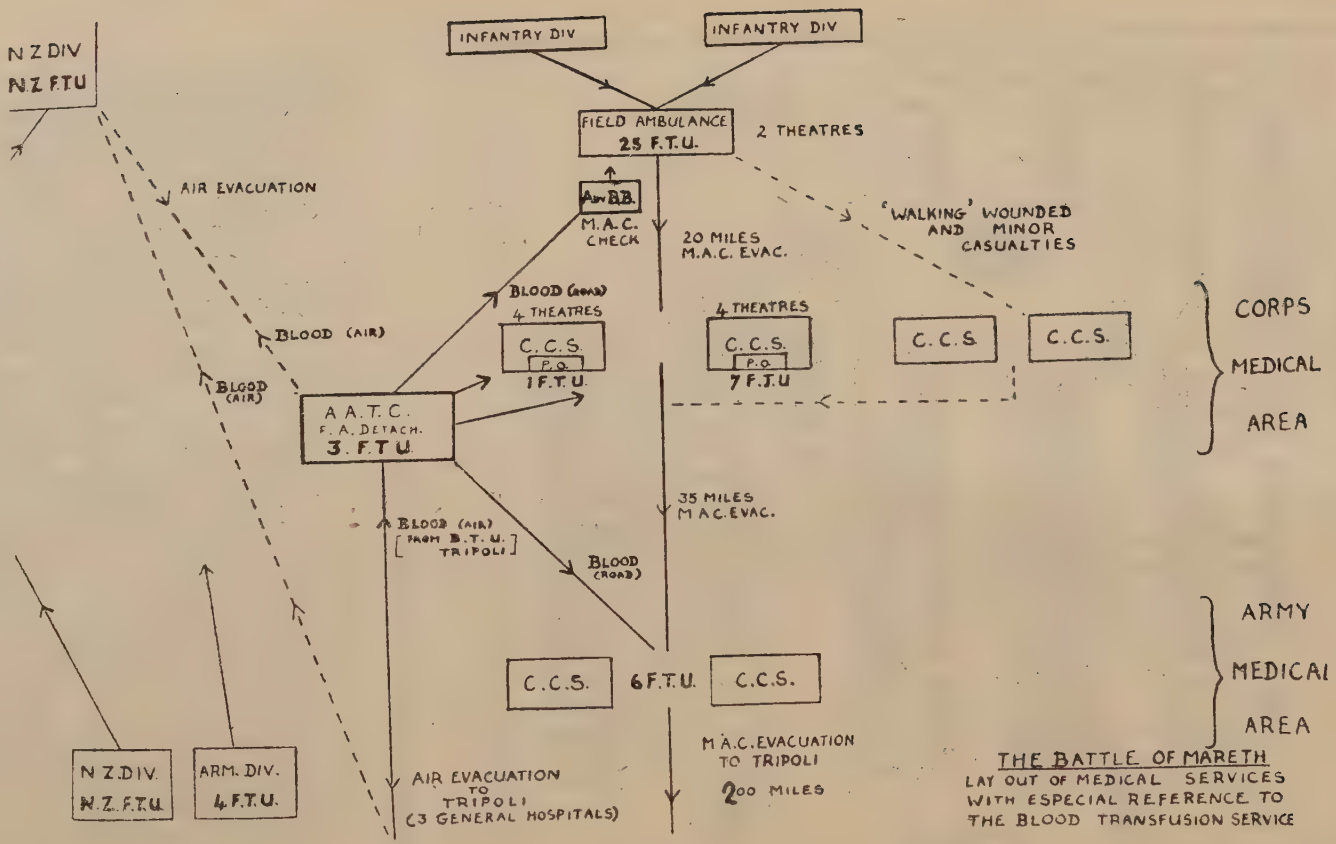


FIG. 4.

Diagram of Transfusion Organization for the Battle of Mareth. No. 3 F.T.U. located at the Advanced Air Transport Centre functioned as a Forward Distributing Section of the Base Transfusion Unit, with Headquarters at Tripoli. An Advanced Blood Bank was established at the forward M.A.C. Check Post Point.

[To face p. 32

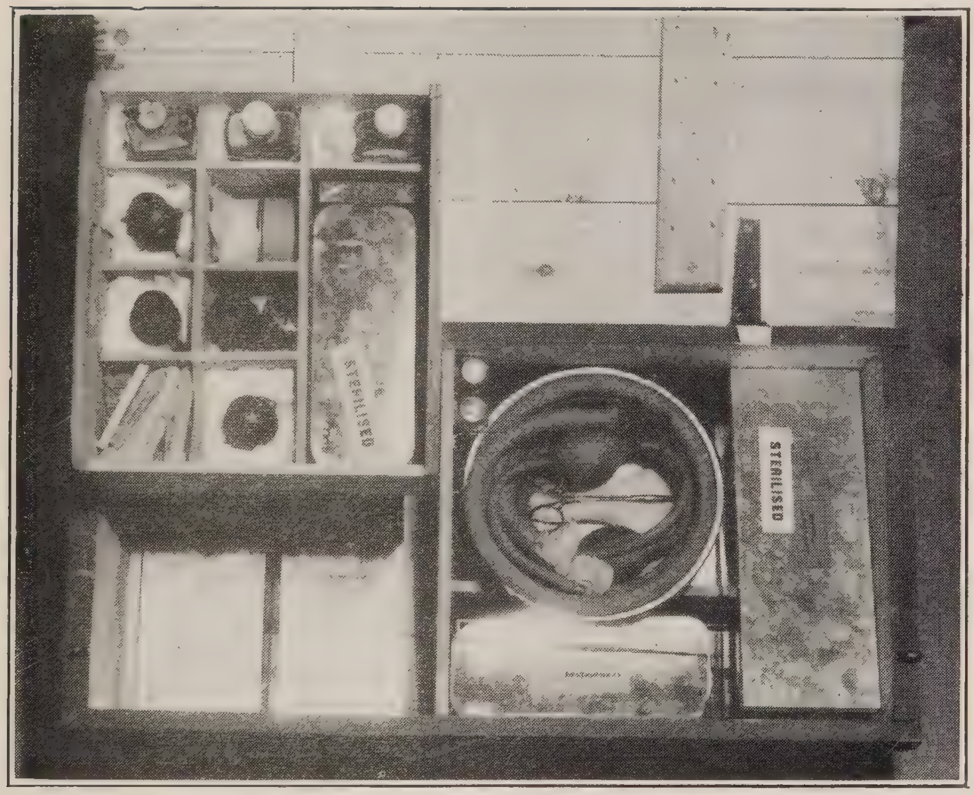


FIG. 5.

Equipment box for Field Transfusion Unit showing disposition of equipment.

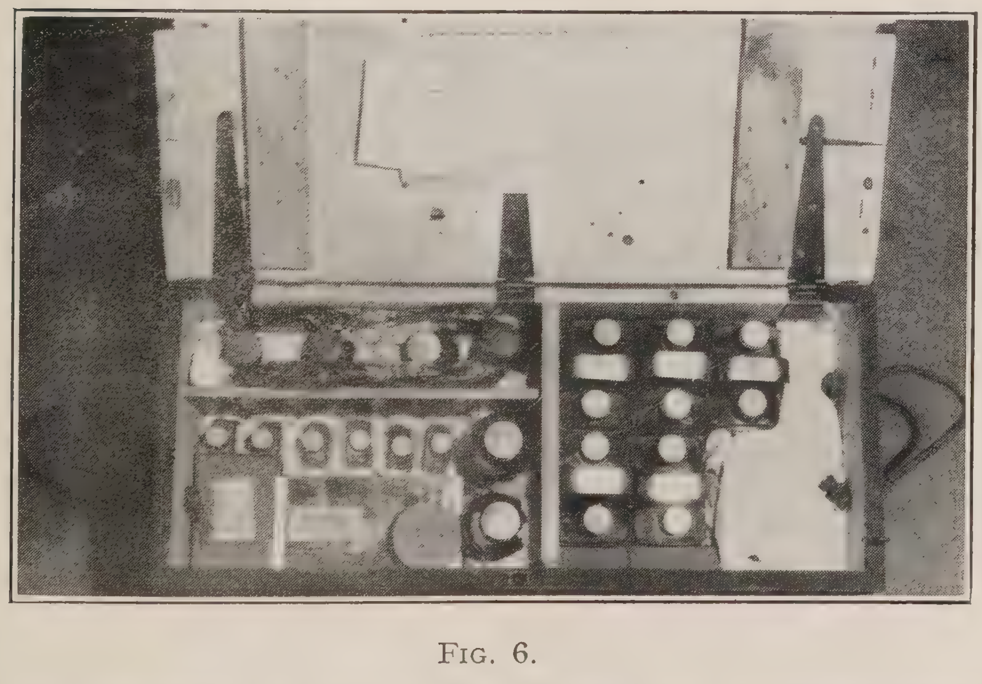


FIG. 6.

Box, Transfusion and Infusion, Field Pattern Box. For general transfusion work by Field Medical Units, on troopships or hospital trains and for small medical units working in isolated positions.

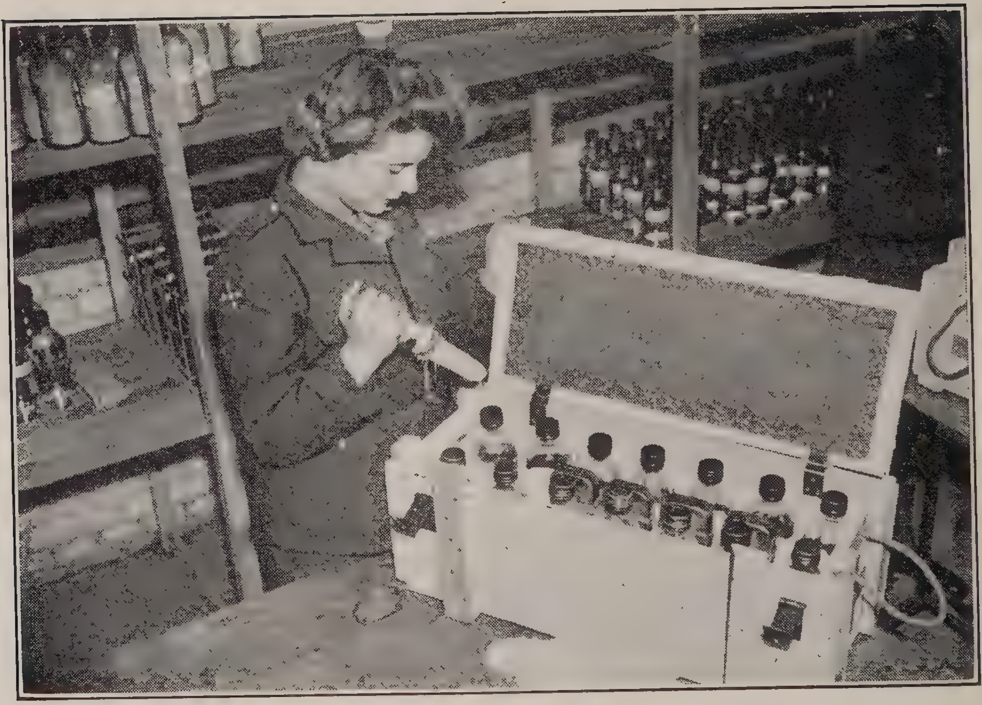


FIG. 7. *[Photograph by courtesy of Norman K. Harrison]*

Standard Plasma Packing Case, with partitions, containing 7 bottles dried plasma, 7 bottles reconstituting fluid and 4 administration sets.

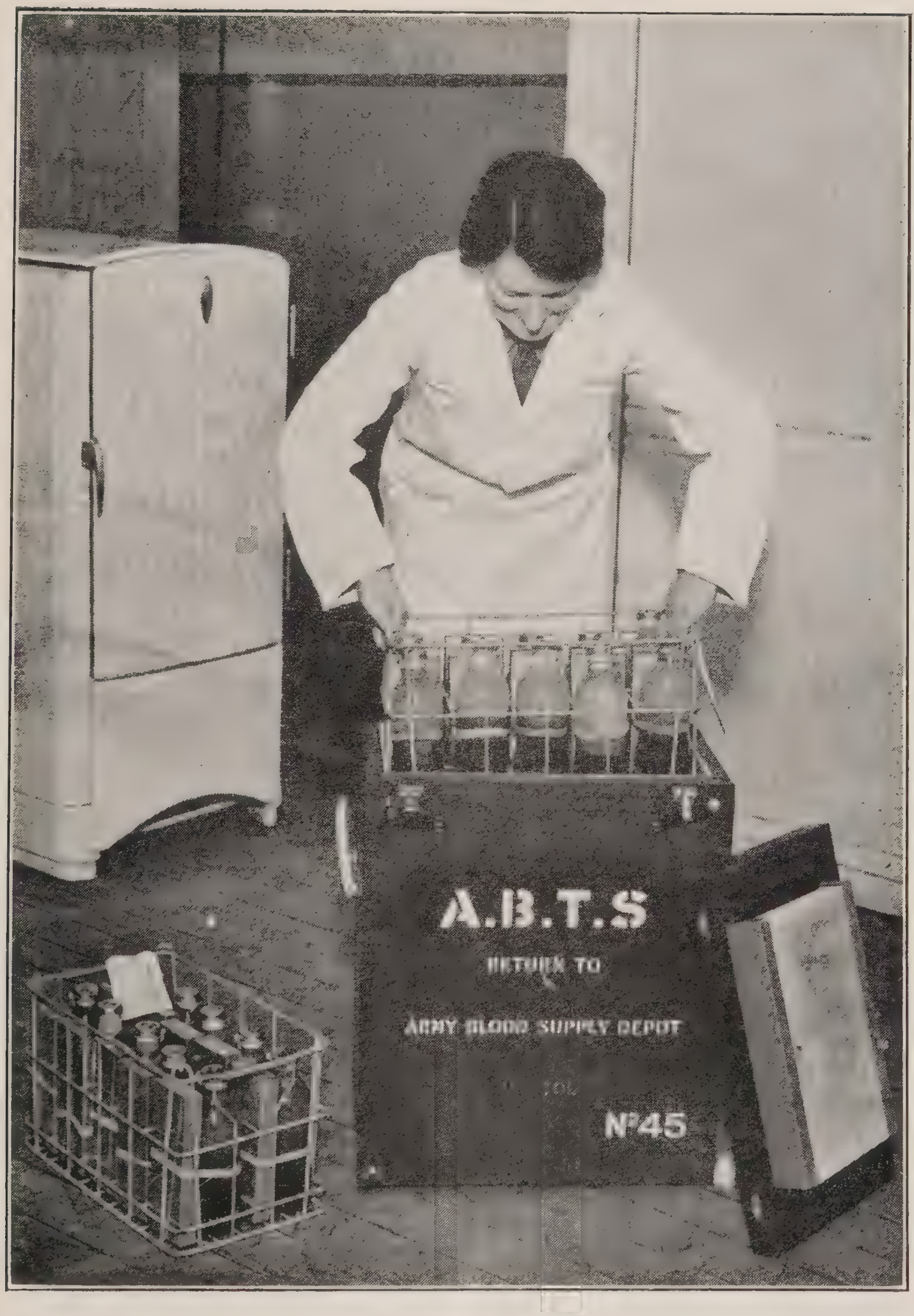


FIG. 8. *[Photograph by courtesy of Norman K. Harrison]*

Insulated Box for air transport of blood. The box holds 20 bottles in crates. Note ice insert in lid.

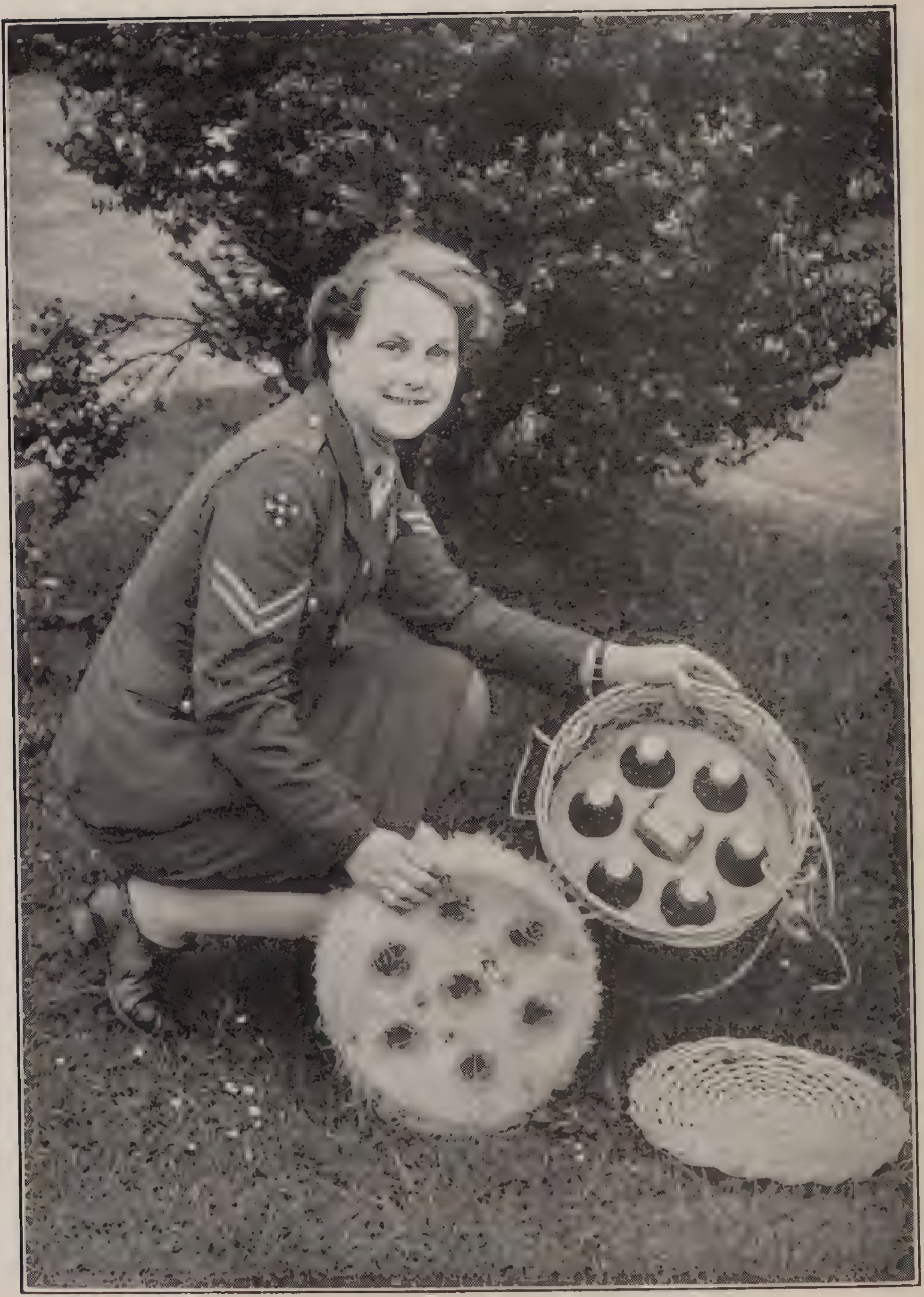


FIG. 9. [*Photograph by courtesy of Norman K. Harrison*

Airborne wicker basket, with Firthflex shock absorbing insert, for dropping transfusion supplies by parachute.

Field Transfusion Units (Home and Overseas)

Field Transfusion units are Field Force units, self-contained with their own medical mobilization scales and war equipment tables. *At home* they may be allotted areas on a geographical basis and come under the orders of the senior administrative medical officer of the area in which they are located. In such an area the Field Transfusion unit officer may be made responsible for all the technical duties connected with transfusion and resuscitation and for the instruction of personnel in all matters pertaining to these subjects. In commands the A.D.P. acts as the command transfusion and resuscitation officer (in addition to his other duties) and is responsible for the co-ordination of all matters connected with this subject including the technical direction of Field Transfusion unit officers within the command. The Field Transfusion unit is responsible for the resuscitation arrangements in the medical unit to which it is attached but is at the disposal of the O.C. this medical unit when not employed on these duties. The duties of an O.C. a Field Transfusion unit include : (1) the keeping of A.D.P. informed of all matters connected with transfusion and resuscitation in the area allotted to him, (2) the supervision by monthly inspection, and, maintenance, of a reasonable and adequate supply of transfusion fluids in all suitable medical units, with an organization for replenishment in case of active operations, (3) the provision and supervision of supplementary dumps of transfusion fluids in places convenient for local needs, (4) the formation and maintenance of local donor panels in suitable medical units, (5) the bleeding of local donors and carrying out of transfusions in the unit to which he is attached, (6) the continuous training of his own unit by means of frequent drills, (7) the institution of schemes of instruction and training in medical units so that officers and men are familiar with simple resuscitation methods and transfusion equipment, (8) the maintenance of close liaison with civilian transfusion services so that mutual assistance may be possible with regard to personnel and supplies.

The nursing orderlies on the strength of a Field Transfusion unit require to be graded and mustered in the trade of Transfusion Orderly ; for this a qualifying examination is held at the Army Blood Supply Depot ; they require also to be trained in the elementary principles of refrigeration, and maintenance of a refrigerator and the execution of small running repairs. The R.A.S.C. driver attached to a Field Transfusion unit needs to be trained in the servicing, operating and maintenance of a refrigerator in addition to his normal duties.

When Overseas.—A Field Transfusion unit is best employed in conjunction with a Field Surgical unit to form a complete Advanced Surgical Centre. The unit is, however, at the disposal of the senior administrative officer, for posting to any place according to local conditions. Supplies are maintained by communication with the Advanced Blood Bank of the Base Transfusion unit.

BASIC SUPPLIES TO MEDICAL UNITS

All medical units are issued with basic supplies of transfusion fluids and equipment. These are disposed as follows :—

1. *Dried Plasma.*—Box (Fig. 7) containing :—

Dried plasma, bottles (400 c.cm.)	no.	7
Glucose-saline (for reconstitution) bottles	no.	7
Administration sets	no.	4

2. *Isotonic Glucose-saline.*—Box containing :—

Isotonic Glucose-saline (540 c.cm.) bottles	no.	20
Administration sets	no.	5

3. *Box, Transfusion and Infusion, Field Pattern* (A.M.S. Form 88 A) (Fig. 6, p. 32). This contains :—

Dried plasma, bottles (400-c.cm.)	no.	5
Glucose-saline (for reconstitution), bottles	no.	5
Administration sets	no.	5
Glucose saline, 540-c.cm. bottles	no.	4
Administration sets	no.	2
Bottles, screw-cap, complete	no.	2
Tins of equipment for taking and giving blood complete) (*see* p. 74, Code letter AG)		1
Bottles, dispensing, screw-cap, containing 120 c.cm. Acid-citrate glucose solution	no.	6
Dried grouping serum, ampoules 1-c.cm.	pairs	1

All components are replaceable after use by indent through the usual channels upon Base Transfusion unit (in the case of a main force overseas) or Army Blood Supply Depot at home, with the exception of equipment for the giving and taking of blood and the giving of glucose-saline, which is designed to be cleaned and used again.

4. *Box, Transfusion and Infusion, Hospital Pattern* (A.M.S. Form 27).—This contains :—

2 tin boxes, 11 in. × 4 in. × 4 in., containing—		
Blood-taking sets (Universal), complete (6 per box)	no.	12
4 tin boxes, 11 in. × 4 in. × 4 in., containing—		
Blood or Saline-giving sets (Hospital Pattern), complete (6 per box)	no.	24
Plugged test tubes containing 4 mm. glass beads (3 per box)	no.	12
2 tin boxes, 11 in. × 4 in. × 4 in., containing—		
4 ft. lengths giving tubing, spare	no.	24
Pull-through brush 0·22 in., for cleaning	no.	1
Glass beads, 4 mm., spare	lb.	1
Bottles, B.T., with suspension band and screw-cap stopper	no.	12
Instructions for use	no.	6
* Stands, telescopic B.T.	no.	3

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* Only issued to Units proceeding Overseas.

The following are the authorized scales of issue of these items to various units :—

	(1) *Boxes Dried Plasma*	(2) *Boxes Glucose-Saline*	(3) *Field Pattern Box*	(4) *Hospital Pattern Box*
Field Ambulance ..	5	1	1	—
Field Dressing Station	5	1	1	—
Field Surgical Unit ..	2	—	1	—
Field Transfusion Unit	30	5	—	1
Casualty Clearing Station	5	5	2	—
General Hospital (200 Beds)	3	1	—	1
General Hospital (600 Beds)	9	3	—	2
General Hospital (1,200 Beds) ..	18	6	—	3

For units working in outlying stations, for troopships and ambulance trains issues are made of an appropriate number of Field Pattern Boxes supplemented by other stores if necessary.

Packing, Transport and Carriage (for weights and measures *see* Appendix, p. 78).—For road, sea or rail transport the standard packing of plasma, fluid or dried, is in boxes with 14 compartments (Fig. 7) which contain either 14 bottles of fluid plasma with 7 administration sets, or 7 bottles of the dried product and 7 bottles of glucose-saline for reconstitution with 4 administration sets ; for crystalloid solutions the standard packing is a 1½ cu. ft. box containing 20 bottles and 5 sets. In special circumstances compartments may be removed to permit packing of 20 bottles of fluid plasma (or 10 dried). Special issues of single bottles of fluid plasma in waterproofed cardboard cartons, and, of 4 bottles with 2 sets in triple carton containers, may also be made where bulk and weight are of importance.

Transport of stored blood requires insulated boxes of known performance. These are of three sizes which carry 20, 10 or 3 bottles. The two first have ice inserts permitting a hold over of from 12–48 hours according to external temperature and are suitable for air, sea, rail or road transport (Fig. 8). The small three-bottle box is designed for hand carriage and has a hold over of from 4–6 hours if efficiently cooled ; it has no ice insert. Supplies of transfusion fluids contained in wicker baskets with shock-absorbing packing may be dropped by parachute (Fig. 9).

NOTES CONCERNING PROCEDURES, EQUIPMENT AND MATERIALS USED IN RESUSCITATION WORK

TRANSFUSION

Equipment

The Army Medical Service transfusion equipment consists of a *Universal Pattern Blood Taking Set* (Fig. 11) and two patterns of administration equipment known as the *Overseas Pattern Giving Set* (Fig. 10) and the *Hospital Pattern Giving Set* (Fig. 11). These are illustrated and described in M.R.C. War Memorandum No. 1

already referred to, in addition to the various Emergency Medica Services patterns which differ in certain details.

(*a*) *Universal Pattern Blood Taking Set* (Fig. 11).—This consists of a two-holed rubber bung which will fit either the screw-cap or K.N.S. type of transfusion bottle. The bung, complete with rubber tubing attachments, air-filter, glass window, intravenous needle with protecting glass tube, is issued wrapped in a calico envelope. After use the set should be immediately dismantled, cleaned and sterilized for a future occasion.

(*b*) *Overseas Pattern Giving Set* (Fig. 10).—This is designed to enable a transfusion to be given under the primitive conditions of active service. An administration set, sterilized ready for immediate use, wrapped in cellophane and contained in a tin box, is issued to the extent of one set for each two bottles of *stored blood* or *fluid plasma*. It is only necessary to remove the cap from the K.N.S. type bottle and perforate the tight-fitting bung with the two stainless steel piercing needles of the administration set. The bottle is then inverted and hung up.

Dried Plasma is issued with a bottle of pyrogen-free distilled water or glucose-saline for reconstitution. The administration set contains one of the special tight-fitting bungs which is inserted after reconstitution has been effected.

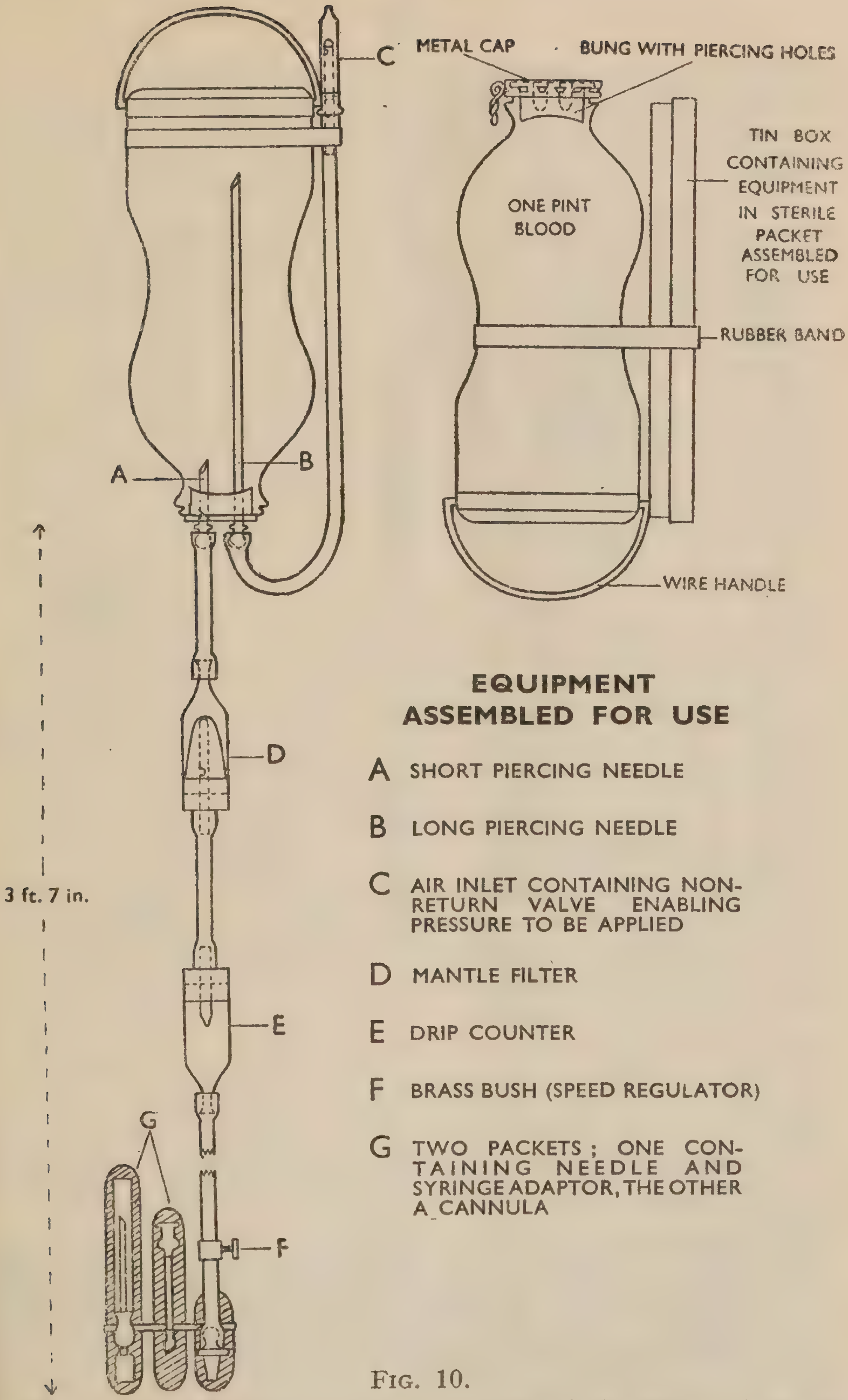
After use all apparatus of this type should be salvaged and returned to Base.

(*c*) *Hospital Giving Set* (Fig. 11).—This is for use in any place where *fresh blood* is taken from a local panel of donors and is designed to be cleaned and re-sterilized for repeated use. The principle is the same as the overseas equipment. Glass beads inserted into the bottle take the place of the mantle filter of the overseas set, while the bung is an ordinary two-holed rubber bung with glass tubes for air inlet and fluid delivery. The bung should be secured in place with a piece of strapping when the apparatus is in use. The same apparatus is used for *glucose-saline* administration but there is then no need to insert beads into the bottle.

A complete schedule of equipment issued by the Army Blood Supply Depot together with explanatory notes is given in Appendix (p. 73).

Blood

Blood, fresh or stored, is an excellent volume-restoring fluid and when of reasonable age, the corpuscles of stored blood endure in the circulation of the recipient and contribute oxygen-carrying power. Old blood contains free pigment and numerous fragile corpuscles; the latter are rapidly destroyed when transfused. Such old blood gives rise to febrile and hæmolytic reactions, accompanied by jaundice. Blood, which is properly and cleanly taken into three per cent. sodium citrate solution to which has been added glucose (pure) to give a final concentration of 0·25–0·5 per cent. (40 c.cm. of a five per cent. solution to a 580-c.cm. bottle), and which is kept at a constant temperature 4–6° C. (38–42° F.), is well



EQUIPMENT ASSEMBLED FOR USE

- **A** SHORT PIERCING NEEDLE
- **B** LONG PIERCING NEEDLE
- **C** AIR INLET CONTAINING NON-RETURN VALVE ENABLING PRESSURE TO BE APPLIED
- **D** MANTLE FILTER
- **E** DRIP COUNTER
- **F** BRASS BUSH (SPEED REGULATOR)
- **G** TWO PACKETS; ONE CONTAINING NEEDLE AND SYRINGE ADAPTOR, THE OTHER A CANNULA

Fig. 10.

The Overseas Pattern Giving Equipment (Code letter AA) for the giving of stored blood and fluid plasma obtained from Army sources. The bottle is the K.N.S. type which is sealed with a clip cap. The bottle is corked with the special tight-fitting white rubber flanged bung. Cannulæ are now issued separately on a scale of 5–30 per medical unit as part of I 1248 equipment.

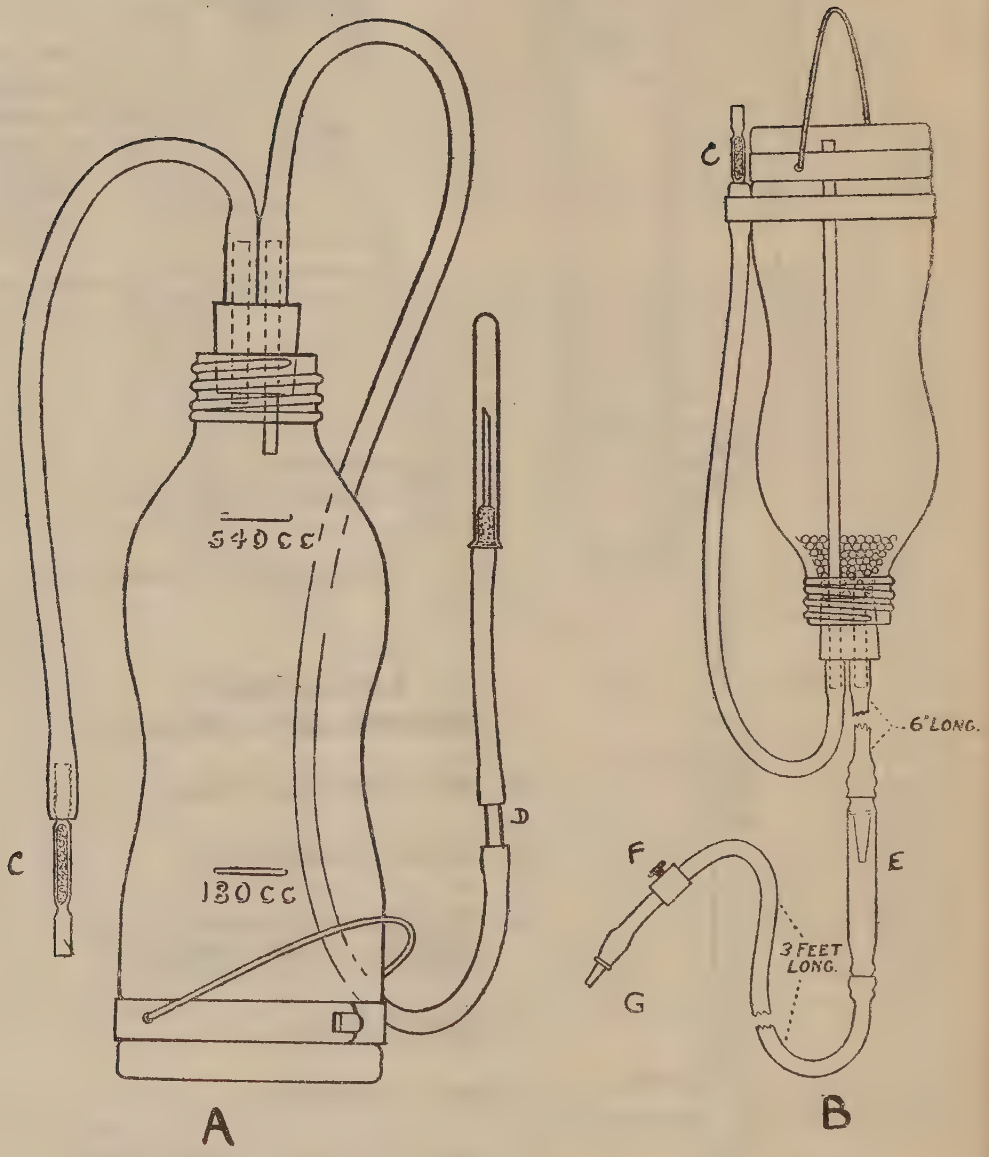


Fig. 11.

A. Universal Pattern Taking Set (Code letter AF) assembled in screw-cap type bottle. C—air filter. D—glass window.

B. Hospital Pattern Giving Set (Code letters AD, ADA) for administration of fresh blood and of blood or plasma supplied from E.M.S. sources. The same set is used for glucose-saline without beads. C—air filter. E—composite all glass drip counter. F—brass bush (speed regulator). G—tubing mount.

preserved for at least four weeks. After this time the blood should be regarded as " old " and, though usable in an emergency up to six weeks, is nevertheless liable to give rise to hæmolytic reactions. Blood up to 14 days' old has almost as much durable oxygen-carrying power as fresh blood, and it is preferable not to use blood older than this.

Good quality stored blood has a sharp line of demarcation between the supernatant plasma and the corpuscles. The line is usually marked by a thin jelly-like clot (often called the " blanket ") composed of leucocytes and platelets. Blood which has been shaken again after having settled once often takes some days to resettle. This is because corpuscles become entangled in the " blanket." This phenomenon is often mistaken for hæmolysis. As blood becomes old, corpuscular pigment diffuses into the supernatant plasma, and blood in which a marked orange tint is obvious more than half-way up the plasma layer (5–6 weeks old) should be regarded as unfit for use. Grossly contaminated blood is characterized by a complete diffusion of pigment throughout the plasma, and the colour is purple red rather than orange. Blood with a diffusely red plasma should never be used.

(*See also* pp. 43, 44. Care of the Blood Bank.)

Temperatures below 4° C. (38° F.) are far more deleterious to blood than are temperatures above 6° C. (42° F.). Low temperatures, particularly freezing, cause rapid hæmolysis. In cold climates it is sometimes necessary to place a hurricane lamp in a refrigerator in order to prevent freezing. Stored blood should be warmed to about 40° C. before being administered. This can be done by placing the bottle in a bucket of warm water. The spring of the metal cap should first be released, in order to avoid the danger of breakage.

The transport of blood presents problems under conditions of war. Slopping and frothing greatly hasten deterioration. To eliminate this trouble Army Blood Transfusion Service bottles are " topped " with a special machine and no slopping can occur. When a receiving unit is within reasonable road or air delivery distance of the Army Blood Supply Depot or Base Transfusion Unit deliveries are made in special insulated boxes which keep the blood cool during transit (Fig. 8).

Whole blood transfusion carries the risk of transmission of syphilis, malaria and infective hepatitis. In stored blood the spirochæte of syphilis survives 3–5 days, the malaria parasite 5–8 days and the virus of infective hepatitis indefinitely. Some protection against malaria is afforded by cinchonization of the donor.

Blood supplied by the Army Blood Supply Depot contains 100 c.cm. three per cent. sodium citrate, 440 c.cm. blood and approximately 40 c.cm. five per cent. glucose ; it is all doubly checked Group O, Universal Donor, blood. Each bottle of blood is tested to exclude syphilis. This Universal Donor blood eliminates the necessity for a grouping test on the recipient. In cases where there is no emergency, and when facilities are available for grouping both donor and recipient, transfusions should be carried out with homologous fresh blood. This is especially desirable in medical cases.

Fluid Plasma

Fluid plasma is obtained by removing the supernatant plasma from blood taken in the proportion of 440 c.cm. blood to 100 c.cm. three per cent. sodium citrate. Plasma can be prepared from overage blood in a blood bank and so avoids waste. A 540-c.cm. bottle yields about 200 c.cm., and it therefore requires the contribution of two to three donors to make 540 c.cm. of plasma. Furthermore, the plasma contains citrate solution in the proportion of two parts in seven and this is soon excreted when transfused. When estimating the amount that needs to be transfused for a permanent effect the volume of the citrate must not be counted, as it is only the water bound by the 4·5 per cent. protein which is retained in the circulation. Plasma prepared by the Army Blood Transfusion Service is rendered agglutinin-free by pooling the blood of heterologous groups and allowing a period of two hours for cross-absorption by the appropriate corpuscles, thus avoiding any danger of hæmolytic reaction in the recipient. After this, the plasma is separated, clarified of fat and passed through a bacterial filter before being finally bottled.

Plasma in good condition is a clear golden or slightly orange fluid. When stored it has a tendency to deposit a small precipitate of fibrin, which does not render it unfit for use. Filtered plasma may also contain clots, either massive or as small fibrin flakes. Provided that the surrounding plasma is still clear, these clots do not prohibit use, but it may be necessary to shake the bottle in order to aerate a large clot so that it floats and thus keeps clear of the outlet. Alternatively, the clot may be speared with the long piercing needle when this is inserted into the bottle. Infected plasma is always diffusely turbid and though turbidity may arise from a harmless cause, namely, incomplete removal of fat, it is safer to discard turbid plasma as unfit for use.

Cold storage in a refrigerator encourages the formation of clots, and bottles should therefore be stored at room temperature in the dark. Shaking has the same effect; bottles are therefore filled to the top in order to reduce shaking. Bright sunlight denatures protein and should be avoided. A temperature of 115° F. applied for 48 hours continuously also causes denaturation. Care is therefore necessary in tropical climates. Denatured plasma is opaque and discoloured. Properly stored plasma keeps at least twelve months.

Plasma, fluid or dried (infra), in that it is filtered, carries no risk of transmitting syphilis or malaria, but filtration does not exclude the virus of infective hepatitis. Plasma transfusion does not lead to Rhesus factor immunization (p. 54).

Fluid Serum

Fluid serum is used for blood-volume restoration and for the treatment of burns in exactly the same way as plasma (pp. 10, 14). It has no oxygen-carrying power and the same recommendation applies concerning the use of one pint of blood in three. Serum differs from plasma in that it contains no fibrinogen. The protein content is about seven per cent. and as serum contains no citrate it has a greater blood-volume restoring power than citrate plasma. Moreover, it is technically easier to prepare in a sterile filtered state than is plasma, and does not present the difficulty of post-filtration clotting. The yield per donor is approximately the same as with plasma. Danger of hæmolytic reaction from agglutinin content is overcome by pooling the serum until the titre has been reduced to a negligible point. On the other hand, there is much experimental and some clinical evidence to show that the incidence of reactions following massive transfusions is greater than with citrated plasma. More experience is necessary before the merits of the two fluids can be confidently assessed. Serum should be stored in a cool, dark place but there is no objection to storing in a refrigerator, except that the bottle has then to be heated before use.

Dried Serum and Dried Plasma

Drying is accomplished by a low temperature, low-pressure process which does not denature the protein.

The material will keep indefinitely in any climate provided drying is complete, and this includes replacement of the air in the bottle with pure dry nitrogen. Sealing has to be very efficient. Dried plasma and serum are the safest materials for transfusion work in the field.

The dried product is reconstituted to its original volume by adding the requisite amount of pyrogen-free sterile distilled water (p. 47) or glucose-saline. Solution is effected in a few minutes, and the resulting fluid is somewhat turbid but this turbidity is normal and does not prohibit use. Once reconstituted the fluid should be used within an hour or so otherwise the added water gives opportunity for any chance contaminating bacteria to multiply to a dangerous degree. The reconstituted product should never be put away for future use, but in the dried state it keeps indefinitely without refrigeration. If the seal of the bottle be imperfect, humid air may enter the bottle, particularly in tropical climates. In these circumstances the plasma eventually becomes denatured. When this is so, a gel is formed on reconstitution and the material is unfit for use. It was originally thought that serum reconstituted at quadruple strength would be particularly effective, especially with burns, in withdrawing plasma from an injured area which would contribute to blood-volume restoration, but experience has shown that such high concentrations of serum are associated with a large incidence of reactions. Reconstituted dried plasma or serum is an efficient blood-volume restoring fluid ; the dried products of 400 c.cm. of fluid plasma or serum are supplied in standard 540-c.cm. blood transfusion bottles and should be reconstituted to a volume of 400 c.cm. Under most service conditions the bottles of the dried product have to be accompanied by a bottle of fluid suitable for reconstitution. The bulk to be transported is therefore double that of the fluid products.

Saline, Glucose and Glucose-saline

The solutions used for intravenous hydration are isotonic with blood. Nowadays, the same solutions are issued for the reconstitution of dried plasma, in order that distilled water (which is equally efficient) may not be administered by itself in mistake for an isotonic crystalloid solution. For rectal administration, half strength physiological saline (0·425 per cent.) is used. When using this route, the solution does not need careful preparation with pyrogen-free distilled water. Hypertonic solutions of glucose and glucose-saline may be used as diuretics, for nutritional purposes, and for dehydration associated with cerebral injury (pp. 17, 47); they have very little place in routine resuscitation work. All intravenous solutions should be made with pyrogen-free water and fine chemicals, preferably of A.R. quality (*see* Preparation of Solutions, pp. 47, 48). The following solutions are obtainable on indent from a Base Transfusion Unit (Overseas) or Army Blood Supply Depot (Home) in bottles × 540 c.cm., unless otherwise stated. Administration sets, which can be used repeatedly, are supplied on a scale of 1 per 4 bottles, when a standard packed box of 20 bottles is issued, or on separate demand.

Isotonic Solutions :

Physiological Saline ..	0·85 per cent. NaCl
Isotonic Glucose	5 per cent. glucose
Isotonic Glucose-Saline ..	0·425 per cent. NaCl; 2·5 per cent. glucose
Isotonic Glucose-Saline	**0·3 per cent. NaCl; 3·3 per cent. glucose.**

For Rectal administration :

Half normal physiological saline : 0·425 per cent. NaCl.

Hypertonic solutions :

5 per cent. glucose in physiological saline—glucose 5 per cent.; NaCl 0·85 per cent.
10 per cent. glucose
50 per cent. glucose—Bottles × 50 c.cm.

The standard solution issued for general use is isotonic glucose-saline containing 0·3 per cent. NaCl and 3·3 per cent. glucose.

Taking of Blood for Immediate Use and for Store

When blood is taken for immediate use, minor contamination from air-borne bacteria is a negligible factor. But when blood is stored, even very small numbers of quite harmless bacteria lead to rapid deterioration and may multiply to a dangerous extent if the blood be removed from the refrigerator and allowed to reach a favourable temperature for a few hours. When blood is taken for store every precaution must be taken to avoid even the slightest contamination.

(*a*) *Taking Blood for Immediate Use.*—The apparatus consists of a screw-cap standard transfusion bottle, a "taking" bung with the appropriate attachments and a "giving" bung with its attachments, as well as beads to act as filter (Fig. 11). All of these have presumably been sterilized in advance and stored in tins or in a dust-free cupboard, or else covered with paper or cloth to prevent the settlement of dust. To the blood transfusion bottle add 100 c.cm. sterile three per cent. sodium citrate. After inserting the "taking" bung the apparatus is ready for use. Sufficient two per cent. procaine should be injected over the selected vein, for preference the median basilic. Skin contamination is rare if the needle is deftly inserted into the vein through the well-cleansed skin in a single operation. During the taking process an assistant should rotate the bottle slowly, in order to ensure even mixing of the blood with the citrate. When the bottle is filled to the 540-c.cm. mark it is only necessary to pour in a test-tube full of sterile beads to act as a filter and change the " taking " bung for the " giving" bung, securing this in position with a little adhesive tape. The blood is then ready for administration.

(*b*) *Taking Blood for Store.*—It is necessary to avoid the minor air-borne contamination which occurs when a screw cap is removed from a bottle or a bung is inserted. It is therefore advisable to add the 100 c.cm. of three per cent. sodium citrate, or 120 c.cm. acid citrate glucose (p. 78), to the bottle and insert the " taking " bung as before and thereafter to re-autoclave the whole apparatus with bung *in situ.* The blood must then be cleanly and quickly taken. If it is proposed to store for more than a week, it is an advantage to add glucose to the extent of 0·25 to 0·5 per cent. The glucose solution has to be autoclaved separately from the sodium citrate, otherwise caramelization occurs, and it is conveniently disposed as a 5 per cent. solution, either in a rubber-capped bottle or a metal screw-capped bottle, which is perforated to allow puncturing of the underlying rubber diaphragm. After removing the needle from the vein of the donor, wipe the needle with a swab soaked in spirit and then plunge it through the rubber cap or diaphragm of the bottle containing glucose ; elevate and invert the glucose-containing bottle and allow about 40 c.cm. of the solution to run in by gravity. This avoids all air-borne contamination. The alternative is to collect the blood into disodium citrate (acid sodium citrate) instead of the more usual trisodium citrate (alkaline sodium citrate). The advantages of the acid compound are that it can be autoclaved together with glucose and that the preservation period is said to be longer. The disadvantage of the acid compound is that clotting occurs more easily ; mixing at the time of collection must be brisk and thorough. For a pint bottle the solution used consists of 2 per cent. disodium citrate, 100 c.cm. ; 15 per cent. glucose, 20 c.cm.

After collecting the blood it is necessary to change the " taking " bung for the metal screw cap of the bottle, which must be done neatly in the proximity of a flame after the manner of all bacteriological manœuvres. Alternatively the two pieces of rubber tubing connected to the " taking " bung may be clipped, or tied off, close to the bung. The bottle, with the screw cap or with the " taking " bung *in situ*, should then be placed in a refrigerator at 4–6° C. (38–42° F.), and not be removed until it is to be warmed ready for use.

CARE OF THE BLOOD BANK

Blood is a good culture medium in which even the chance saprophytic contaminant is highly dangerous if the temperature at which the blood is stored be allowed to rise above the growth restraining point for more than a short period. Experience has shown that, even with highly skilled blood collection, from 1–5 per cent. of bottles may contain an odd contaminant derived from the skin or the air. Unfortunately, such minor contamination does not always reveal itself by visible hæmolysis, even when the bacterial population has been allowed to multiply. A quite innocent-looking bottle of blood may, therefore, contain highly potent toxins, which have been known to be rapidly fatal in a dose of as little as 50 c.cm. *The only safeguard is immediate, continuous and accurate refrigeration.* Blood must be refrigerated as soon as possible after collection, and should be maintained between 4–6° C. (38–42° F.) until it is required for use. Inefficient and intermittent refrigeration carries grave risks. The following are good general rules :—

Control.—A blood bank should be under the control of a medical officer whose special duty it is to make issues therefrom, under personal supervision. Issues should not be delegated to nurses, orderlies or porters, who are usually unaware of the visual characters of good stored blood (p. 8) and who are apt to be guided by date rather than appearance (p. 39). The officer should keep a constant check on the efficiency of the refrigerator, preferably with a recording thermometer or a maximum and minimum thermometer. He should inspect the bank daily, and immediately discard all bottles which are out of date or which have a suspicious appearance.

Temperature and Transport.—Though blood kept at a temperature a few degrees higher than 6° C. does not rapidly deteriorate, nevertheless, every degree of rise relaxes the restraint on bacterial multiplication. The temperature of stored blood should not be allowed to rise above 6° C. (42° F.) until just before it is required for use. When transported from one point to another, the blood must be carried in cooled insulated boxes (Fig. 8) of known performance, and be received into a refrigerator immediately it reaches its destination. It is the provision of this constant chain of refrigeration which constitutes one of the difficulties in maintaining a safe blood service in the field. Half-hearted gestures with lumps of ice are potentially dangerous. Indeed, it is inadvisable to put loose ice in contact with bottles of blood, in that corpuscles nearest the side of the bottle tend to become fragile and later, hæmolysed.

Warming up.—When removed from the refrigerator, the clip-cap of the bottle must be loosened in order to prevent breakage. Preferably, but not necessarily, the blood should be warmed to 37° C. (98° F.) before administration. Blood that has been out of the refrigerator for more than a few hours, at most about 6 hours in a temperate climate, should be discarded.

Blood taken from a refrigerator and allowed to warm up should on no account be restored to the refrigerator for use on a future occasion.

TRANSFUSION REACTIONS

1. **Mis-matched Transfusion**

A frankly incompatible transfusion, *i.e.* when the transfused cells are incompatible with the recipient's serum, usually gives rise to distressing symptoms after only a few cubic centimetres have been transfused. These symptoms include respiratory distress, rigors, *pain in the back* and vomiting, and may rapidly be followed by unconsciousness, with sudden collapse and death if the transfusion be continued. In other cases the initial symptoms may not be immediately fatal but there are later signs of the inevitable intravascular agglutination and hæmolysis, such as jaundice, hæmoglobinuria, embolic phenomena and urticaria. Death may occur within a few hours or a few days, from cerebral embolus or renal failure. This last has for long been attributed to blocking of the renal tubules with a pigment of the hæmatin order which is readily precipitated in an acid medium ; this leads to anuria and uræmia. The alternative explanation of the renal failure is that it is due to arterial spasm and ischæmia brought about by substances liberated from the destroyed corpuscles.

When such symptoms occur the transfusion should be stopped at once, whilst every effort should be made to alkalinize the urine and to promote simple diuresis, in order to facilitate the elimination of the pigment. Alkalinization also assists in the relief of arterial spasm. To ensure continuous alkalinity of the urine, as well as a good urinary output, a large amount of fluid and of alkali is required (*see* pp. 46, 47).

An alternative treatment worthy of trial is the prompt transfusion of 200–300 c.cm. of compatible blood ; this is said to relieve spasm at once. Splanchnic block coupled with medical measures to start diuresis is also said to be effective.

2. Mild Reactions

Reactions of a less serious nature following within a few hours of transfusion arise from a number of causes ; they may include fever, rigors, urticaria, jaundice, hæmoglobinuria, general malaise and sometimes an asthmatic attack. Jaundice and hæmoglobinuria are usual after the transfusion of old stored blood containing much free pigment or large numbers of fragile corpuscles. With really old blood the intravascular hæmolysis may be severe enough to cause a rapidly fatal issue as in the case of gross incompatibility. The treatment is the same as for mis-matched transfusión. Relatively mild, but similar, hæmolytic reactions may occur occasionally owing to high titre agglutinins present in the transfused blood, which may react with the recipient's corpuscles. Such reactions are theoretically possible whenever Group O blood is transfused to a heterologous group, but the chance of such a reaction is small, because the agglutinin titre is rarely high, whilst the diluting effect of the recipient's own blood immediately reduces the titre to a negligible level. Nevertheless, with a massive transfusion into a recipient whose blood volume has been greatly reduced by hæmorrhage, the titre of the agglutinins contributed may be within the active limits, and such a hæmolytic reaction is usually of the type with delayed symptoms. Serum and plasma transfusions carry the same risks unless precautions are taken to remove agglutinins by pooling or by absorption. The treatment is the same as for mis-matched transfusion. Fever and rigors may be caused by unclean apparatus, pyrogen-containing distilled water, hæmolytic reactions, or sometimes by blood taken from a donor soon after a meal, when a tendency to produce allergic manifestations is also said to be more common. Rigors are sometimes due to transfusions being carried out at too rapid a rate. In such cases a reduction in speed is almost immediately effective.

3. Inapparent Reactions

This term is used to describe a transfusion in which, though there are no presenting reactionary symptoms, the transfused blood nevertheless fails to achieve the anticipated rise in hæmoglobin for more than a short period. The transfused cells do not survive for any reasonable time. When there is no obvious explanation for such a result the cause is usually an intra-group incompatability involving most commonly the Rh factor (p. 54) ; rarities such as the Sub-groups of A may sometimes be concerned. This phenomenon arises especially with multiple transfusions.

4. Infected Blood

Blood in which infection is not revealed by obvious hæmolysis (p. 44) may nevertheless contain living bacteria. If refrigeration has been imperfect even aerial and skin saprophytes will multiply and produce toxins that may rapidly cause a fatal result. Symptoms may appear with as little as 50 c.cm. ; they include respiratory distress, cerebral symptoms, rigor, vomiting, diarrhœa and loss of sphincter control.

5. Air Embolism

A surprisingly large volume of air can be tolerated by a healthy subject, but no more than a few cubic centimetres may cause death in a patient gravely ill. Fatal air embolism may occur from the level of blood falling below the exit tube, especially if positive pressure has been applied ; from failing to displace air from the tubing before connecting it to the needle ; from ill-fitting and perished rubber tubing, and, from placing a ligature through a vein instead of around it when tying in a cannula.

URINARY OUTPUT, ALKALINIZATION OF URINE AND DIURETICS

An adequate excretion (1,500 c.cm. per day) of alkaline urine is essential in cases of mis-matched transfusion (p. 44), crush syndrome (p. 14) and when chemotherapy may be complicated by oliguria or urinary suppression.

Oral Route.—The fluid intake to ensure adequate urinary output must reach at least 3,000 c.cm. per day. Sodium bicarbonate, 2 drams hourly by mouth, will achieve fairly rapid alkalinization, which may be maintained by administering 8 drams per 24 hours. Sodium citrate may also be used, but the amount required for efficient alkalinization is the large amount of 35 g. This sometimes produces tetany, whilst many people rapidly develop a dislike for the taste even when it is disguised with flavourings. A single dose of 8 g. will alkalinize the urine in half an hour. The balance of the 35 g. needs to be taken during the following 24 hours, and thereafter 35 g. daily.

Intravenous Route.—When speed is essential, when vomiting precludes oral administration or when hydration is being carried out entirely by the intravenous route, the choice of drug lies between sodium citrate, sodium bicarbonate and sodium lactate. Three per cent. sodium citrate is useful for immediate administration in an amount of 150 c.cm., but for continuous alkalinization as much as 18 g. is required in the 24 hours, and this may produce tetany. When sodium citrate is used, the daily requirement of fluid is supplied by 2,400 c.cm. of glucose (5 per cent.) and 600 c.cm. sodium citrate (3 per cent.). Sodium bicarbonate is used as a 1·4 per cent. solution, but as it decomposes on heating sterilization is difficult. Two to three litres a day are required to maintain an alkaline urine in the average case. In an emergency, a measured amount may be dissolved in sterile water and injected without sterilization. Sodium lactate ($\frac{1}{6}$ molar) has neither of the disadvantages of the other two ; it may be made up in small bottles of 50 c.cm., in tenfold strength and diluted ten times before use. Sodium lactate has come into use because it is stable either alone or in Ringer's solution ; it is non-irritating, and can be sterilized by autoclaving or boiling, and it has a further advantage over sodium bicarbonate, in that its action is not so rapid as to carry the danger of converting an uncompensated acidosis into an uncompensated alkalosis. In the body, the sodium ion is liberated, and appears in the body fluids chiefly as sodium bicarbonate, while the lactate radicle is partly oxidized and partly converted to glycogen. In the normal individual, the urine becomes alkaline within half an hour of the intravenous injection of 30–60 c.cm./kg. body weight of a $\frac{1}{6}$ molar solution, but the change in urinary reaction may be delayed in those with hepatic damage or in whom dehydration has led to a lowering of electrolyte content of the body fluids, particularly of chloride ion. For alkalinization of the urine, especially in crush injuries, and in oliguria or urinary suppression following chemotherapy, the usually recommended dose is 30 c.cm./kg. body weight of a $\frac{1}{6}$ molar solution, given intravenously. The average requirement in 24 hours is 1–2 litres of this solution (20–40 g.).

Preparation.—A molar solution is first prepared by neutralizing 100 c.cm. lactic acid with 60 per cent. sodium hydroxide (free of sodium bicarbonate) using phenol red as the indicator. Dilute to 800 c.cm. and boil for 30–40 minutes, adjusting the reaction again, if necessary, by the addition of further sodium hydroxide.

Finally, dilute further to 1 litre and autoclave. A $\frac{1}{6}$ molar solution of sodium lactate is prepared by diluting the molar solution 1 : 5 with sterile distilled pyrogen-free water.

Diuretics.—50–100 c.cm. of hypertonic glucose (10 per cent.) intravenously is a simple and efficient diuretic. Sodium sulphate (4·3 per cent.) in the same dose and by the same route may also be used.

PREPARATION OF SOLUTIONS FOR INTRAVENOUS USE

The three solutions mainly required are sodium citrate, isotonic glucose-saline and physiological saline (p. 41). All of these are stable at autoclave temperature, provided the chemicals themselves are of fine quality. None but the finest quality, preferably AR, sodium chloride and dextrose should be used. Pyrogenic reactions occur when the distilled water used for solution has not been obtained from a still fitted with sufficient baffle plates to prevent the carry-over by splash of the bodies of fever-producing bacteria. The bacterial bodies constitute a foreign protein which induces a febrile reaction.

Nevertheless, it is possible to render pyrogen-containing distilled water fit for use, whilst even a good quality ordinary boiled water can also be employed. Such waters may be cleared of bacterial bodies either by filtration through a Seitz filter, using an S.B. pad, or by sprinkling in finely powdered charcoal, which absorbs the bacteria ; the charcoal is afterwards removed by filtration through ordinary filter paper. The charcoal is added in an amount of 1 g. per litre and is well shaken for 15 minutes.

Distilled water once made should be used immediately. Stale distilled water, however stored, is always exposed to air-borne contamination, which includes bacteria capable of multiplying even in this theoretically unsatisfying medium.

Solutions for intravenous use should be made with freshly distilled water and be distributed into their final containers ; they should then be autoclaved immediately. If this is done the solutions keep indefinitely, but otherwise there is a great tendency for the solution (sodium citrate especially) to grow moulds. As with stored blood, the main principle is to allow a small number of air-borne contaminating bacteria no opportunity to multiply. Poor quality glucose caramelizes when autoclaved and also hydrolyses to yield an undesirable acid product. Failing A.R. quality the glucose must be of sufficient purity to avoid these two drawbacks. Glucose cannot be autoclaved as a mixture with ordinary tri-sodium citrate because the alkalinity of the latter causes caramelization. Acid disodium citrate has not this disadvantage and the virtues of this anticoagulant are described on p. 43. With poor quality glucose, a solution for intravenous use should be made up in freshly distilled water and sterilized by steaming on three successive days or by boiling for 30 minutes.

CARE AND CLEANING OF APPARATUS FOR REPEATED USE

Pyrogenic reactions are caused as commonly by unclean apparatus as by pyrogen-containing solutions. Apparatus used for intravenous work must be scrupulously clean, and it is not always easy to ensure that glassware, rubber tubing and the other equipment used for transfusion work are thoroughly cleaned for repeated use. New rubber tubing contains pyrogenic material, which must be removed by boiling for an hour in 0·1–0·2 per cent. caustic soda. After this the tubing should be pulled through, boiled in distilled water and then cleaned as described below.

As a general rule, the cleaning process should be started immediately after use, especially after transfusions of blood. A thorough soaking in clean, *cold* water is the first essential, as this dissolves pigment and loosens clots so that they can be easily dislodged. All apparatus should be dismantled and soaked in cold water for several hours. The bottles should then be washed in hot water, using a stiff test-tube brush to ensure thorough cleaning, whilst glass tubing can be cleaned with a pipe cleaner. Rubber tubing is best cleaned with a jet of hot water, by fixing the tubing on a dispenser's tap. Failing this a 0·22 rifle pull-through brush or a stiff wire pull-through are quite efficient. Glass beads should be cleaned by swirling them in a tin with hot water so that the beads rub rapidly one against another. Needles should be cleaned out with a stilette and afterwards washed through with a jet of water from a syringe.

Thick rubber tubing can be autoclaved many times without deterioration, but thin tubing needs to be renewed after being used three or four times. In each case unfitness for use is shown by loss of elasticity. Rubber tubing should never be stored in rooms which are subjected to extremes of temperature.

BLOOD GROUPING *

Blood grouping is carried out with the sera of blood groups A and B, which contain the agglutinins Anti-B (β) and Anti-A (α) respectively. With these two sera it is possible to detect the four blood groups. In ordinary practice it is customary to mix a drop of each of the sera with a drop of the blood under test and to observe the occurrence or absence of the phenomenon of hæmagglutination. If agglutination occurs with Anti-A only, the subject belongs to Group B; if with Anti-B only, he belongs to Group A; if with both Anti-A and Anti-B, he belongs to Group AB; if agglutination occurs with neither, he belongs to Group O. It should be borne in mind that the reaction is essentially a quantitative one and that easy reading is dependent upon a number of factors. In the first place, it is necessary for the test sera to be of high titre and also what is called " avid." Such sera will cause a reaction, usually within one minute, whereas weak sera may take as long as an hour to react, and even then the agglutination may be so feeble that a microscope is necessary to detect it. This is especially so with subgroups A_2 and A_2B the cells of which are relatively insensitive to agglutination with Anti-A serum. Testing serum must be selected so that it will detect the insensitive A_2 factor otherwise serious errors occur (p. 54). High titre serum may rapidly lose its power if improperly stored, exposed to sunlight or from a number of other factors, including the addition of antiseptics. Testing sera should preferably be frozen solid and kept in the dark, but as this is rarely possible under service conditions, grouping serum is now dried by a low temperature, low pressure process in which state it is preserved indefinitely without cold storage.

In the second place, the test needs to be arranged so that the serum has the greatest opportunity of action, and so that obscuring phenomena are reduced to a minimum. There should always be an excess of serum as compared with the corpuscles under test. In practice, these conditions are best achieved by diluting the test blood with saline (p. 50). Dilution of the blood also reduces the amount of pseudo-agglutination (rouleaux formation) which occurs whenever blood is shed and which, if very marked, may be mistaken for true hæmagglutination (p. 52).

When carrying out grouping tests it is advisable to test a number together rather than perform single tests, because the normal distribution of the groups (AB: 2 per cent., A: 46 per cent., B: 8 per cent., O: 44 per cent.) may then be observed and a rough check is available as to the suitability of the test serum. Thus,

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* *See also* M.R.C. War Memorandum No. 9, " The Determination of Blood Groups." 1943. H.M. Stationery Office.

impotent serum, which fails to detect groups AB, A and B, would erroneously indicate that all those tested belonged to Group O, whereas infected serum, which has pan-agglutinating properties (p. 52), would suggest that all belonged to Group AB. Such results in a reasonable-sized number of subjects under test would be so abnormal as to cast grave suspicions on the goodness of the test sera.

In relation to pan-agglutination it should be borne in mind that the fault may lie with the corpuscles under test as much as with the test sera, and that it is particularly likely to arise if the saline corpuscle suspensions are not tested when fresh but are allowed to lie about overnight or longer. An odd skin contaminant present in such a suspension quickly multiplies and so introduces this complication.

Army Blood Grouping Serum

In the field, the main problem has been the supply of reliable grouping serum which will remain potent under all climatic conditions, which will not become infected and for which refrigeration is not required.

The standard product is a dried grouping serum supplied in glass-sealed nitrogen-filled tubes with a desiccating substance (indicator silica-gel) contained in the tube. The indicator is blue when dry, and pink when damp ; it thus affords visual evidence of the suitability of the serum. The slightest trace of moisture causes a rapid deterioration of dried serum. Once a tube has been opened, it is advisable to use it without delay, and to discard any excess. It is difficult to re-seal effectively ; plasticine is supplied with the outfit, which may form a good seal for a day or two, but re-sealing in the flame always introduces water of condensation. To assist in eliminating errors, the A (anti-B) serum is coloured Amber, and the B (anti-A) serum, Blue ; the labels on the tubes are likewise coloured. The serum is disposed in tubes containing the equivalent of 1 c.cm. of the natural fluid product. The equipment provided consists of an ampoule each of A and B dried serum, four microscope slides, china pencil, glass file, a needle and a lump of plasticine.

Grouping Technique

Reliable results are obtained only by using a strict routine with careful attention to detail and by allowing a sufficient time interval before reading the results. The haphazard mixing of a drop of undiluted blood with a large mass of the dried powder produces a preparation which prohibits even expert reading, whilst failure to wash a pipette or loop in between different operations may cause serious errors.

The tests may be carried out on slides, on a white porcelain tile or in tubes. In the field, the first two are most commonly used. The *blood* for test should be diluted, either with physiological saline or 3 per cent. sodium citrate, to make an approximately 5 per cent. suspension of corpuscles. This may be done by adding one good-sized drop of blood to 1 c.cm. of the diluent in a small tube. The suspension has a faint pink opalescence ; with unmeasured amounts, the pink opalescence is a sufficient guide to accuracy. The saline or citrate diluent must be sterile and should be freshly made where possible.

The *dried serum*, contained in a standard tube, is shaken into a clean dry test-tube, to which is added 1 c.cm. of sterile water. The tube is shaken until complete solution occurs. Solution should be rapid. If a gel appears the sample is unsuitable.

Apparatus.—With a china pencil mark the slide or tile into equal left and right-hand spaces and label them A and B respectively. Distribution of the reagents may be made with pipettes or wire loops. It is preferable to have three, one for the A serum, one for the B serum and one for the blood samples. This avoids mixing high titre sera. Otherwise, most careful washing between all operations is essential. Loops need to be dipped in water, flamed and then cooled in water between successive operations.

Distribution of Reagents.—With a Pasteur pipette, or wire loop, distribute one drop (0·05 c.cm.) of the reconstituted A serum into all the A spaces. With the second pipette, or loop, distribute one drop of reconstituted B serum into the B spaces. With the third pipette, or loop, add one drop of the well-mixed corpuscle suspension to its respective A and B space. When using a loop, the sample should be well stirred into the serum drop, and the loop cleaned, as described above, between each mixing. With a pipette, the corpuscle suspension can be dropped on to the drops of serum and the pipette washed out between each blood sample.

Reading the Result.—Rock the slide or tile gently for half a minute and then allow it to stand. After at least 10 minutes, and before 15 minutes have passed, the tiles are agitated more stongly. Agglutination, if present, can easily be seen. In cases of doubt, examine with a hand lens.

Variations in Technique.

(*a*) Reconstitution of the serum with water is recommended. Nevertheless, the serum can be used dry, taking a pinch of the dry powder, no larger than a pin's head, which is rapidly stirred into a drop (0·05 c.cm.) of the *diluted* blood.

(*b*) The use of diluted blood as a routine is strongly recommended. In an emergency, undiluted blood may have to be used. In these circumstances, use a *very small* drop of blood well stirred into a drop (0·05 c.cm.) of the *reconstituted* serum. *Undiluted blood and dry powdered serum should never be used.*

The Direct Matching Test.—Direct matching of donors' cells against the recipient's serum before transfusion is always advisable, especially when blood groups other than O are used. The direct method should not be considered a substitute for blood grouping tests, which should always be made when grouping sera are available. Under battle conditions, when only Group O blood is supplied, the direct match will usually have to be omitted, but in back areas, when transfusions are more deliberate, the test should be carried out.

The technique of the test is the same as that described above save that the serum of the recipient takes the place of the reconstituted A and B sera. Sufficient serum for the test can be obtained from a few drops of blood taken from the ear and allowed to clot in a small tube, or from 0·5 c.cm. of blood taken from a vein.

Precautions

1. Controls with known A and B corpuscles should always be included in any series of grouping tests. This eliminates errors arising from impotent or infected sera.
2. Grouping tests should be carried out immediately on the fresh diluted blood samples. In any case, the delay should be no longer than 36 hours after taking the sample, and if there is delay, the samples should be placed in a refrigerator at 2–4° C.
3. Infected reagents, such as saline or citrate, infected glassware and infected corpuscle suspensions, are liable to give rise to the so-called Thomsen phenomenon of pan-agglutination. When this is the case, the corpuscles are agglutinated non-specifically by all sera. The phenomenon should be suspected whenever a series of grouping tests appears to give rise to an unusually high incidence of Group AB (*see* Table, p. 53). This source of error is extremely important and can be avoided with certainty only by carrying out grouping tests with fresh corpuscles and with clean glassware and reagents. Pilot tubes attached to blood bottles issued from a blood bank are particularly prone to exhibit this phenomenon when the direct cross-matching test is carried out.
4. Infected fluid serum may likewise give false positive results but may equally well give false negatives because heavy infection of serum leads to loss of potency. Infection of serum is usually obvious from the smell.

Difficulties in Interpretation

Pseudo-agglutination or rouleaux formation rarely gives rise to difficulty if diluted blood is used ; it may be prominent if both blood and serum are undiluted. The addition of a drop of saline to the serum-cell mixture usually abolishes the phenomenon, whereas true agglutination is unaffected.

Another common cause of difficulty with rouleaux formation is delay in reading the result when using the tile or slide method. The preparation should never be allowed to dry.

Intense rouleaux formation is rarely seen in the blood of healthy people, but in certain pathological states, particularly septic conditions with high fever, the determination of the blood group may be difficult. Differentiation between rouleaux formation and true agglutination may be made in some cases by examining a drop of the preparation under the microscope. Tapping the coverslip will usually disperse small rouleaux but has no effect on agglutinated clumps.

Cold Agglutination.—In certain pathological states, and in quite a number of apparently normal individuals, the serum may contain true agglutinins which act only at low temperatures and are hence called cold agglutinins. Occasionally they are active at room temperature and, very rarely, at or just below body temperature. Most cold agglutinins are non-specific and will agglutinate

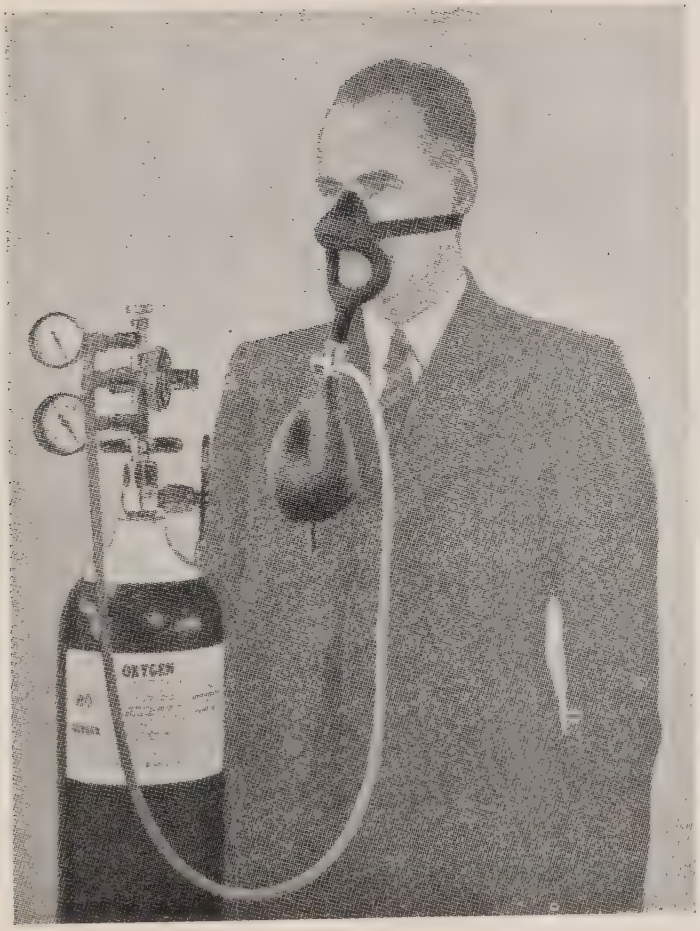


FIG. 12.

Apparatus Oxygen B.L.B. (Pattern B)

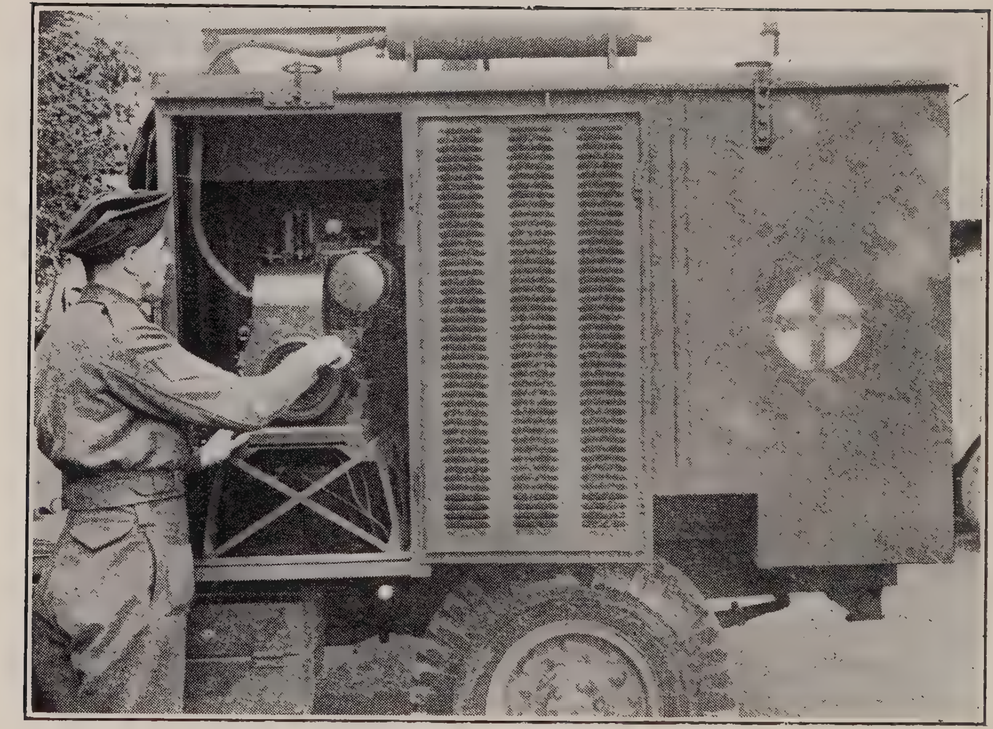


FIG. 13.

Starting the engine for the battery charging generator. (Type A refrigerator van.)

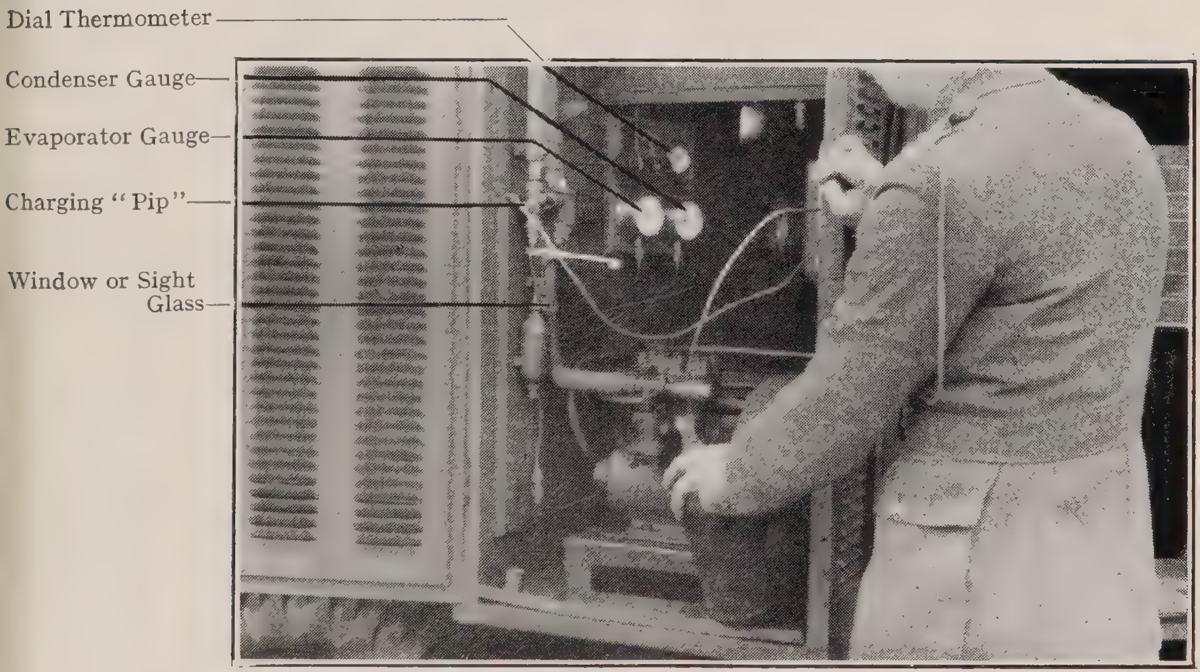


FIG. 14.

Maintenance of type A refrigerator. To show position of gauges and indicators. The operator has connected the methyl chloride gas cylinder to the charging pip.

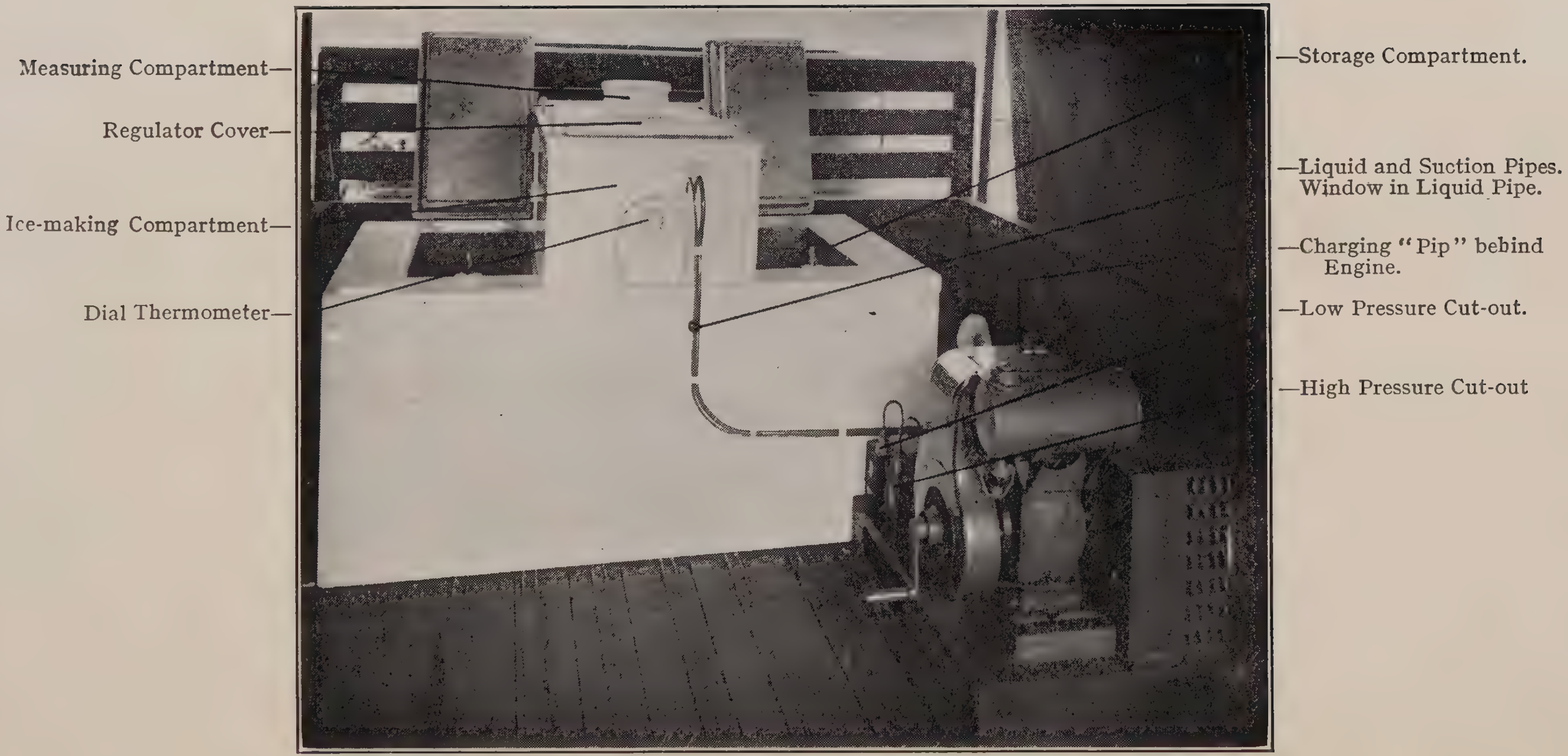


FIG. 15.

The Type E (Smithfield) Refrigerator.

all human red cells, irrespective of the Landsteiner blood group. Because they will agglutinate even the cells of the person in whom they occur, they are often called *autoagglutinins*. The best clinical example of cold agglutination is paroxysmal hæmoglobinuria.

Non-specific cold agglutinins, active at room temperature, lead to difficulties in both the grouping test and the direct matching test. In grouping, the unwashed red cells may be agglutinated regardless of the testing serum so that the group is incorrectly identified as AB, whilst in direct matching the patient's serum will be found to agglutinate all prospective donors' cells. Whenever a result of this type is obtained cold agglutination is almost always the explanation and one or more of the following procedures must be carried out: (1) Perform the tests at 37° C., having warmed all reagents to this temperature before mixing. (2) Free the red cells from cold agglutinins by two or three washings in saline at 37° C.; the washed cells are used for the grouping test. (3) Free the autogenous serum used for the direct matching test from cold agglutinins by allowing the clotted blood to remain in the refrigerator for some hours, shaking from time to time. Under these conditions, the cells shaken free from the clot absorb most (usually not all) of the cold agglutinins from the serum, which needs to be separated finally in the cold before being used for the direct matching test.

Refinements of Blood Grouping

The routine described in the foregoing applies largely to emergency work. When there is not the need for haste, and particularly when a panel of guaranteed donors is being established, additional precautions are desirable in order to eliminate clerical and technical errors. This is particularly so with Group O donors in whom, at least, the clerical entry should always be re-checked by a second test on an independent occasion. But full confirmation of a blood group, from the technical aspect, can be obtained only by demonstrating not merely the presence or absence of the inherited agglutinogens (A and B) in the corpuscles, which is what the routine technique does, but also the presence or absence of the complementary agglutinins (anti-A and anti-B) in the serum. These are tested for with known A and B corpuscles. The full technique for blood grouping, therefore, requires separate samples of the corpuscles and of the serum.

The composition of the four Landsteiner groups of human blood is as follows :—

Blood Group	*Agglutinogen in Corpuscles*	*Agglutinin in Serum*	*Approximate Distribution*
AB	AB	O	2 per cent.
A	A	Anti-B	46 ,,
B	B	Anti-A	8 ,,
O	O	Anti-A and Anti-B	44 ,,

Thus the full proof that a subject belongs to Group O is given by finding that his corpuscles are inagglutinable by anti-A and anti-B sera, whilst his serum will agglutinate both A and B corpuscles. If these conditions are fulfilled the subject can belong only to Group O. But should the serum be found to contain only the anti-B agglutinin, a serious doubt is cast on the result. Similarly, the validity of a corpuscular Group B is in doubt if the serum be found to contain no agglutinin at all. These two examples, Group O and Group B, are given because they afford two of the commonest instances of errors in blood grouping when nothing more than the routine corpuscular test is employed. The errors arise because of the so-called sub-groups of A.

Sub-Groups of A.—It is now universally recognized that there are at least two kinds of A agglutinogen and that bloods of sub-groups A_1 and A_1B and A_2 and A_2B occur. The main difference between the sub-groups is that the corpuscles of A_2 and particularly A_2B react far more weakly with anti-A testing serum than do the corpuscles of A_1 and A_1B. Hence, when testing sera are being selected, it is very important to choose those sufficiently potent to detect the relatively insensitive A_2 factor. It will be appreciated that, with weak sera, sub-groups A_2 and A_2B will tend to be classified as O and B respectively owing to failure to detect the A_2 factor. Hence the advisability of checking the agglutinin content of the serum of so-called Group O and Group B donors, as indicated in the foregoing paragraph. When agglutinins are found to be deficient in subjects whom the routine corpuscular test shows to belong to Group O and Group B, the explanation is usually that the true blood group is A_2 or A_2B respectively. The disastrous results which would follow the use of such wrongly classified donors are obvious.

When transfusions are given to recipients of Groups A and AB, it is not necessary to use blood of the appropriate sub-group, except in the very rare cases where the recipient has become sensitized by a previous transfusion.

Rhesus Group

Human red corpuscles contain a variety of factors in addition to the A and B agglutinogens of Landsteiner. These other agglutinogens, of which M and N have until recently been the best known, are usually ignored in the selection of blood donors because the corresponding agglutinins occur very rarely in human sera and are hardly ever stimulated by the transfusion of the agglutinogen.

But it is now known that the corpuscles of 85 per cent. of human subjects, irrespective of their ABO group, contain a Rhesus (Rh) agglutinogen, so called from the fact that a similar one is found in the red cells of Rhesus monkeys. It has been found that the remaining 15 per cent. of persons whose corpuscles lack the Rh agglutinogen (so-called Rh−) are liable to form the corresponding agglutinin if this agglutinogen be introduced into the circulation. This may occur in all Rhesus negative persons as a sequel to the transfusion of Rhesus positive blood, and in Rhesus negative women who become pregnant with a fœtus whose corpuscles are Rhesus positive. From the transfusion point of view it should be clearly understood that the 85 per cent. who have the good fortune to be born Rh+do not run any risk of this complication ; it is confined to Rh− individuals and, even then, occurs only under one of the two conditions described above. Anti-Rhesus agglutinins are not found naturally as are anti-A and anti-B agglutinins ; in the male they come into being only *after* an actual transfusion. But once the anti-Rhesus agglutinin has been produced it may reach a high titre and, at a subsequent transfusion, promote a severe hæmolytic reaction which may even be fatal. From the Army point of view the possibility of this complication must always be considered when multiple transfusions are necessary, and particularly if there is an interval of ten days or more between transfusions. Thus under field conditions, when transfusion of blood is practised in a forward area and needs to be repeated at a base hospital, this form of hæmolytic reaction may easily occur. No such complications are caused by plasma transfusions and this is a strong argument for the free use of plasma in forward areas.

It would obviously be an advantage if a simple test for the Rhesus factor could be included in routine grouping tests. But this is not feasible. Not only is a special technique required but also a supply of a number of samples of reliable and potent anti-Rhesus sera, which are difficult to obtain. The test has not reached a stage when dried serum can be issued. The test itself is performed, as described below, against not only the unknown corpuscles, but also against known Rh+ and Rh− corpuscles. It is hardly applicable to field work and the direct match test takes its place.

Refinements of the Direct Matching Test. (*Intra-Group Compatibility*)

Incompatibilities from factors other than ABO may arise in the case of those subjected to multiple transfusions and in the case of pregnant women. As described above these incompatibilities are confined, for practical purposes, to the Rhesus factor. The direct matching test for Rhesus incompatibility requires a special technique and considerable experience in reading. Expert advice from a pathologist should be sought in all cases where this factor is likely to be involved.

The recipient's serum needs to be tested against not less than two known Rhesus positive and Rhesus negative bloods, as well as against the cells of the proposed donor or donors. Prepare approximately 1 per cent. suspensions of the cells under test (0·02 c.cm. blood to 1 c.cm. saline). Add one volume of each suspension to one volume of the test serum in a small tube (7 mm. diameter). Place the tubes in a water bath or incubator at 37° C. for one or, preferably, two hours. Remove without shaking and examine the sediment with a hand lens. A homogeneous sediment with a clear-cut edge indicates a negative reaction. With a positive reaction the sediment appears granular and has a serrated edge. The occurrence of agglutination should be confirmed by *gently* withdrawing some of the sediment and examining it microscopically. It will be realized that anti-Rh agglutinins are immune bodies and that there are favourable as well as unfavourable times for demonstrating them. Thus shortly after the transfusion of an Rh+ blood to a recipient whose serum contains anti-Rhesus agglutinins, these last disappear completely (by absorption) from the circulation, and may not become detectable for some five days or more. Thereafter the potency will increase and later wane.

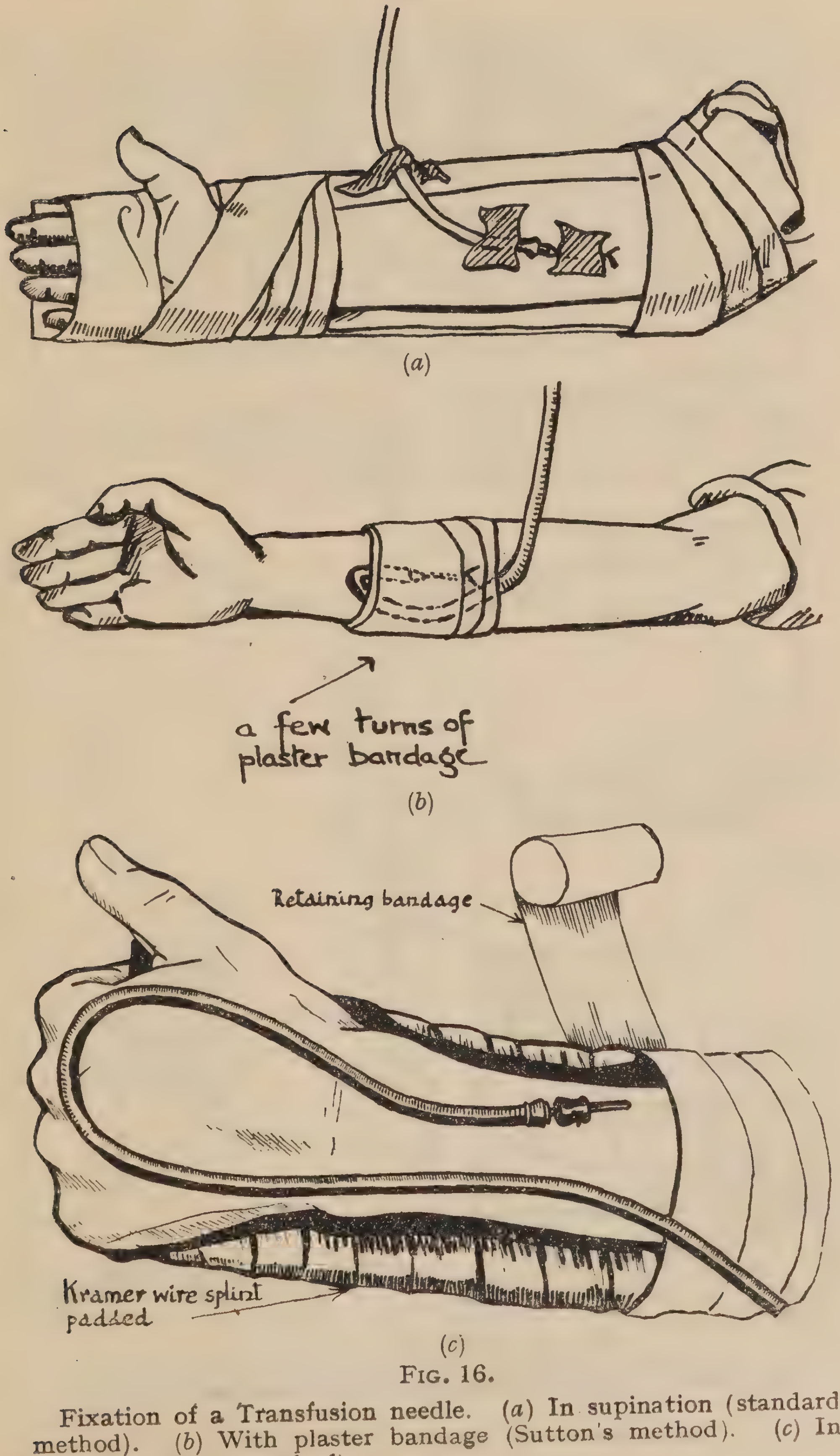
METHODS OF ARRESTING HÆMORRHAGE

Continuing hæmorrhage leads to progressive reduction in blood-volume, thereby increasing the symptoms of shock. The resuscitation officer should therefore be equipped to stop all external sources of bleeding by firm bandaging over a wide area, with forceps, with ligature or with a tourniquet. Bandaging is preferable to most of the recognized patterns of tourniquet. Unrevealed sources of bleeding must obviously be left until the patient reaches an operating theatre. All casualties to whom a tourniquet has been applied as a first-aid measure should have the wound inspected to observe whether the application has been efficient. In most cases it is not advisable, in a resuscitation ward, to remove a tourniquet from those whose limbs will obviously need amputation, even where it is surmised that bleeding will not recur. Removal of a tourniquet is always followed by plasma loss into the injured tissue, which may produce serious shock. There has been much controversy as to the proper use of a tourniquet ; the modern view is that more harm than good often follows its use, as its application for any length of time allows no alternative to amputation. Many limbs that might otherwise be saved become devitalized by tourniquet apparatus. Firm bandaging with several layers of wool, not only at the site but also embracing and supporting the whole limb, is just as effective in arresting hæmorrhage and limiting plasma loss, and it allows the surgeon more scope for conservative measures.

INSERTION AND FIXATION OF A TRANSFUSION NEEDLE

A vein in the antecubital fossa, usually temptingly obvious, is not the best site either with a restless patient, or with long-continued transfusions, or when the patient has to be moved with a transfusion in progress. Even though the arm be splinted, a restless patient is likely to bend the arm slightly and so displace the needle. An accessible forearm vein is preferable.

The standard method of splinting is with the arm in supination (Fig. 16*a*), and is satisfactorily carried out with a padded Cramer wire splint, bent a few degrees to allow slight flexion at the elbow. Important points are : that the upper bandage be sufficiently loose to avoid constricting the veins, and that the palm of the hand be securely fixed in supination by several turns of broad (preferably 4-inch) bandage. If the patient is able to pronate at all it will be possible for him to flex the elbow to a degree which can cause displacement of the needle. For secure fixation, it is essential that the needle be truly within the vein, and that it be pushed up the lumen for a distance of at least ½ inch. Retention of the needle can then be achieved by a short length of ½-inch adhesive strapping passing across the broad hilt of the needle. Dry skin and a dry needle are necessary for firm adherence of the strapping. Alternatively, a length of 3-inch " Elastoplast " can be applied, covering the puncture site and the needle as far as its junction with the needle mount. It is advisable to keep the junction outside the strapping, to facilitate change of set, should this be necessary. The rubber tubing is fixed to the forearm by a further length of strapping, and finally, in a like manner to the splint. This prevents any pull on the tubing being communicated to the needle (Fig. 16*a*).



(a)

(b)

(c)

FIG. 16.

Fixation of a Transfusion needle. (*a*) In supination (standard method). (*b*) With plaster bandage (Sutton's method). (*c*) In pronation (Muir's method).

An alternative procedure (Sutton's method), of especial value in cases of long-continued transfusion, is to insert the needle well into a forearm vein, and encase the whole in a few turns of 4-inch plaster of Paris bandage (Fig. 16*b*). This secures absolute fixation of the needle. Further splinting of the arm is then seldom necessary and free movement of the arm is permitted.

A third method, Muir's method (Fig. 16*c*), is to fix the arm in pronation, the Cramer wire splint having been bent to support the natural curve of the arm in this position. It is claimed that the position of pronation is more comfortable than supination for long-continued transfusions.

TRANSFUSION DURING TRANSPORTATION

Stretchers

During the relatively short time when a stretcher patient is being manhandled, say from a ward to an ambulance, it is convenient to have a means of suspending a transfusion bottle so that it has neither to be carried by hand nor laid precariously on the stretcher.

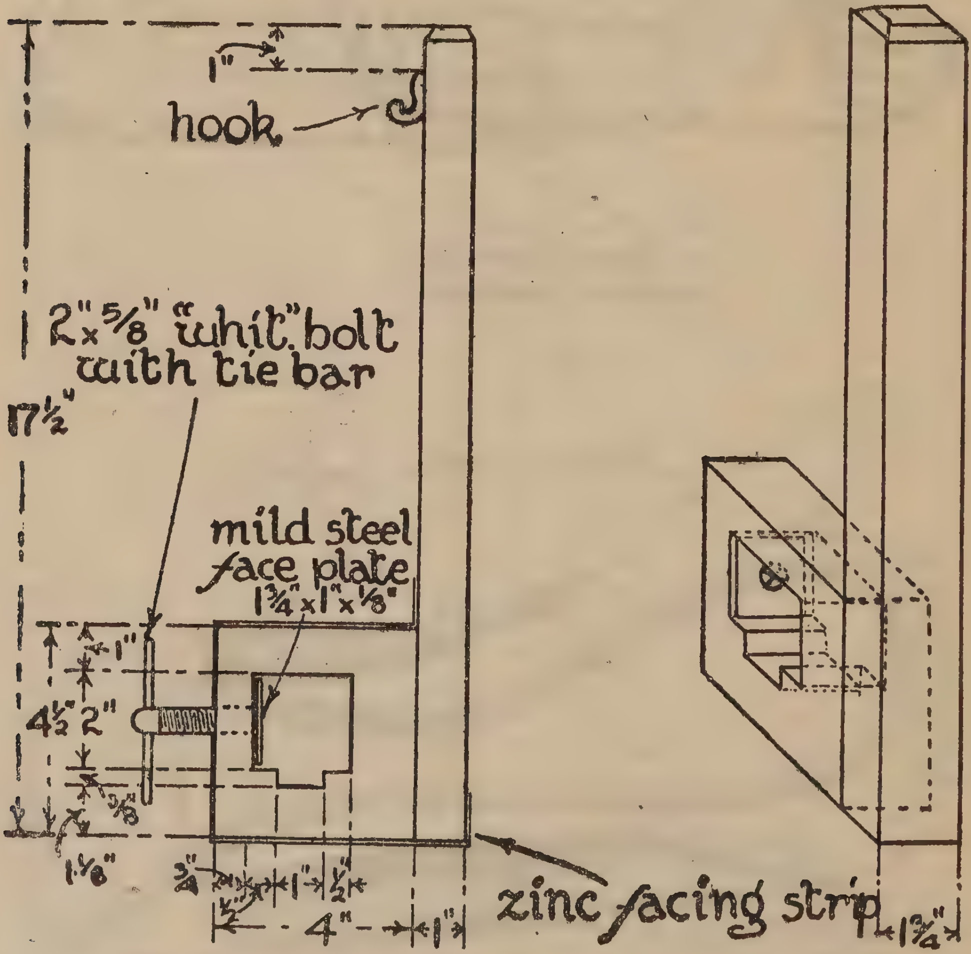

1"
hook
2"x5/8" "whit." bolt with tie bar
17½"
mild steel face plate 1¾"x1"x⅛"
1"
4½"
2"
3/8"
1⅛"
¾"
½"
1"
½"
4"
1"
zinc facing strip
1¾"

FIG. 17.

Stretcher Transfusion stand for use while carrying stretcher.

Details of a suitable stand, which can readily be made from 1 × ¾-in. wood, are shown in Fig. 17. The life of the stand will be prolonged if the base block which slips over the stretcher handle be reinforced with zinc strip or banding metal. The stand will slide into an ambulance without fouling either the guiding rails or the stretcher on the top bunk. When it is not possible to obtain a bolt and steel face plate, the stand may be pushed on to the stretcher handle and fixed with a wooden wedge firmly driven into the position which the face plate is shown to occupy in the diagram. When the stretcher is in place in the ambulance, the stand must be detached, as it does not permit of sufficient height for an efficient gravity feed. For transfusion during an ambulance journey, one of the following methods may be used.

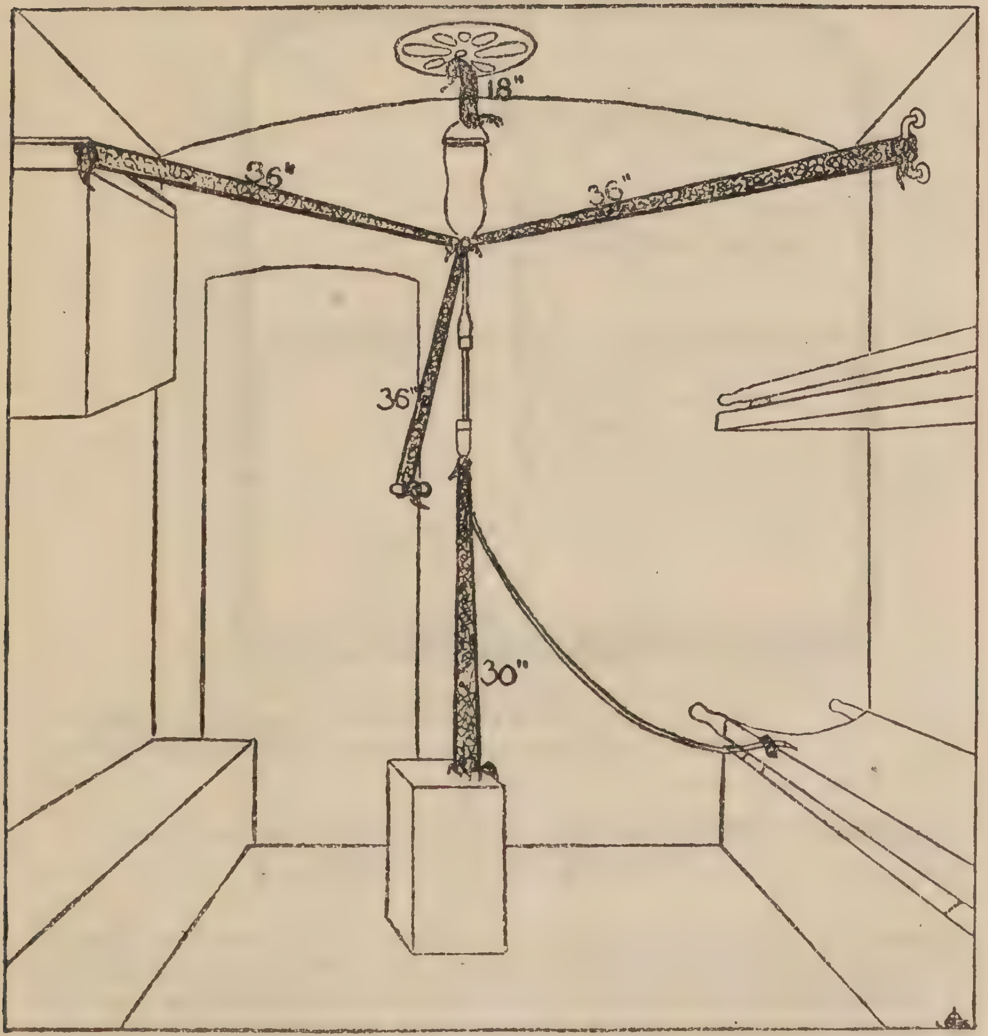


FIG. 18.

Method of suspending and fixing a transfusion bottle for an ambulance journey (Lucas's method).

Ambulance

The following are two methods for setting up a travelling transfusion during an ambulance journey. The first method requires no special apparatus, and has been applied successfully both in ambulance planes and hospital ships. Whichever method be used, *the needle needs to be firmly fixed*, as described in the preceding section. Cannulation is rarely necessary.

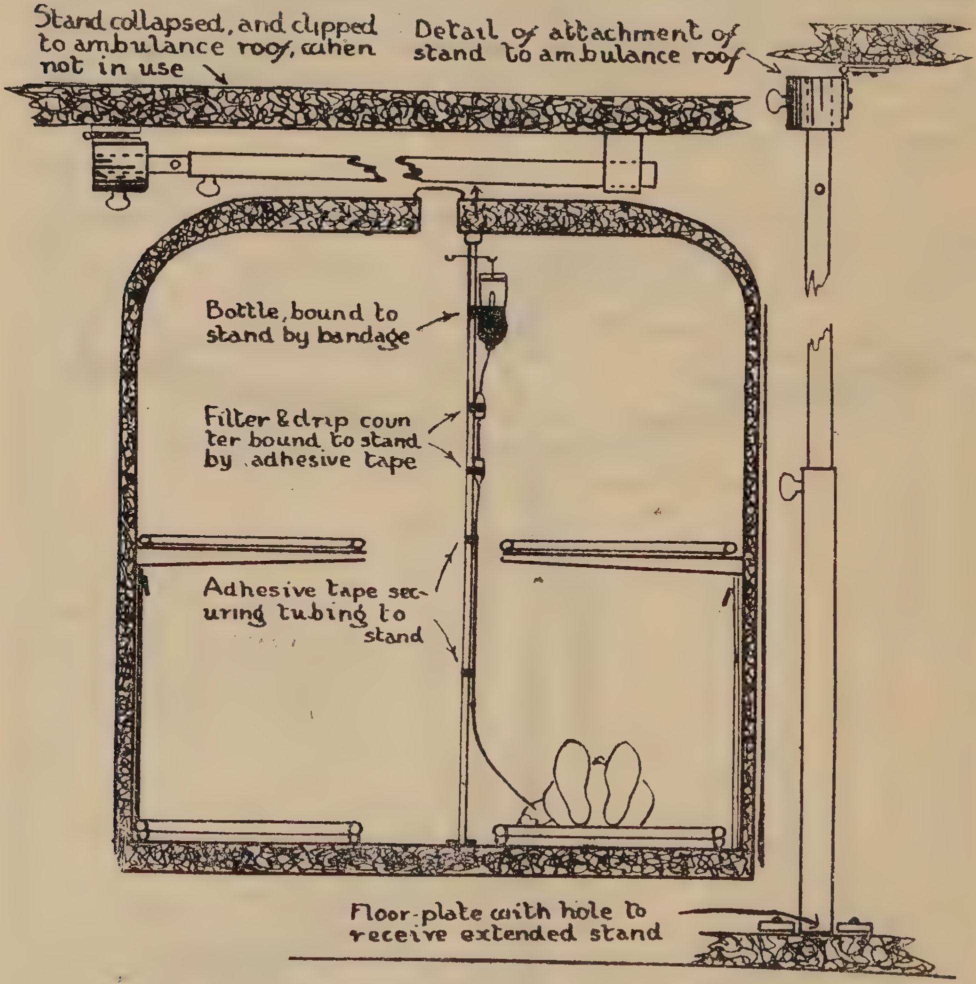

Stand collapsed, and clipped to ambulance roof, when not in use
Detail of attachment of stand to ambulance roof
Bottle, bound to stand by bandage
Filter & drip coun ter bound to stand by adhesive tape
Adhesive tape sec- uring tubing to stand
Floor-plate with hole to receive extended stand

FIG. 19.

Suspension and fixation of transfusion bottle, using standard telescopic transfusion stand.

Ventilator Attachment (Lucas's Method).—This may be used in the Mark IV, four-berth, K2 ambulance car. In other models where no ventilator exists, its place may be taken by a hook in the roof. The stretcher is placed on the lower bunk with the transfusion arm on the inboard side. A number of pieces of 4-inch cotton bandage are attached to the giving set in the following manner: A piece, 18 inches long, is looped through the suspension band, which is tied to the forward ventilator in the roof of the ambulance. Three pieces, 36 inches long, are tied firmly to the lower end of the neck of the bottle ; these are used as stays, two being fixed to the hand grips just below the roof and the third to the latch of the door at the forward end of the compartment. A piece of bandage, 30 inches long, is attached to the drip counter, and is then anchored to a full two-gallon petrol or water can such as all ambulances carry ; this is placed immediately below the set (Fig. 18). Two such transfusions can be set up side by side for two patients in the lower bunks.

An alternative method is to use four pieces of bandage 4 feet long, all of which are attached to the neck of the bottle ; three are fixed as above and one to the petrol can which may with advantage be laid on its side ; the drip counter is then anchored to the taut vertical bandage with adhesive tape. If no petrol can is available the bandage may be tied to the lowest stretcher guide rail.

Permanent Attachment (A.B.S.D. Method).—The Standard Army Telescopic Transfusion Stand is utilized. The base plate is removed and a collar with hinge is brazed at the top end. This is fixed to the roof just in rear of the ventilator (Fig. 19). A small floor plate with hole is fitted to receive the end of the stand. A clip in the roof holds the stand, in the shut-up position, when not in use. This supplies suspension hooks and a rigid rod to which the bottle, filter cover and drip counter may be fixed, so that they do not swing during the journey. The bottle is tied firmly to the stand by two figure-of-eight pieces of bandage, one at the waist of the bottle and one at the neck ; the filter cover, drip counter and rubber tubing can be conveniently fixed with adhesive tape.

The alternative method, less convenient, is to use the stand with base plate, the latter being bored with three holes, through which it can be fixed to the floor with screws.

When ambulance transfusion is carried out, it is essential to have an orderly in attendance in order to shut off the flow when the bottle is finished, otherwise there is a danger of air embolism. The orderly should also be capable of adjusting a needle and the rate of flow.

STERNAL TRANSFUSION

The introduction of transfusion fluids into the circulation *via* the sternal bone marrow is now an established clinical procedure. This route may sometimes be of use in the treatment of casualties where intravenous infusion is not practicable. Such occasions may arise in extensively burned cases where the only alternative to sternal transfusion is to cut down through the burned area, or, very rarely, in severely shocked patients whose arm veins are not available, and whose leg veins are in such intense spasm as to resist the introduction of fluid, even under pressure.

The advantages of the sternal route are that difficulties occasioned by spasm of the veins do not arise, that fixation of the needle is extremely good, and thus the movement of patients is greatly facilitated ; and that the technique is simple. On the strength of these points in its favour, sternal transfusion has been advocated by some as the method of choice. There are, however, very definite drawbacks : special apparatus is required, and there is some danger of penetrating the posterior plate of the sternum, especially if the operation has to be performed hastily. This may well result in a fatal mediastinitis. Furthermore, osteomyelitis and septicæmia have been known to arise even with the needle correctly sited. Moreover, it is seldom possible to introduce fluids at the rapid rates which are usually necessary in the treatment of badly shocked patients.

The chief use of this method is likely to be found in cases requiring massive transfusions over prolonged periods, rather than in the initial treatment of severely shocked casualties, where, however, it may have to be used as a last resource.

A specially designed trocar and cannula, or needle, with wings for attachment by strapping to the skin, and, an accurately fitting stilette, is the best form of apparatus. But an ordinary Salah sternal puncture needle is efficient and though the standard Army transfusion needle is not ideal, by reason of its length, its finely tapered point and absence of a fitted stilette, it was, nevertheless, used with success on several occasions in the African campaign.

The stilette should be withdrawn so that it does not project as far as the bevel of the needle, whilst the upper end should be bent over the hub. It is advisable to improvise a safety guard by screwing a transfusion flow regulator on to the needle at a distance of 1·5 cm. from the point.

The best site for puncture is in the mid-line just above the angle of Louis. The skin at this point should be anæsthetized and the underlying periosteum well impregnated with local anæsthetic. The needle, with stilette in place, should be held at a right angle to the manubrium and, with a firm screwing motion, pushed through the outer bony plate. Proof that the needle is in the marrow cavity must be obtained by removing the stilette and attaching a syringe, when it should be possible easily to withdraw a marrow-blood mixture. The syringe is then detached and the transfusion tube put in its place. It will be found that the transfusion fluid will flow quite freely at about 80–100 drops/min. The rate may be increased by the application of positive pressure to the transfusion bottle, but this usually causes intense pain.

Continuous Gastric Suction

Abdominal cases during the first four to five days of the post-operative period are frequently hydrated entirely by the intravenous route. In order to relieve distension the gastric secretion is removed by continuous suction. In the absence of a suction pump a satisfactory apparatus can be devised from transfusion equipment as shown in Fig. 20, which is self-explanatory. The apparatus is connected to a Ryle's tube when this is *in situ* in the stomach. Alternatives to Ryle's tube are a No. 8 rubber catheter or an 18-inch piece of giving-set rubber tubing (soft variety) in which a few holes should be cut with scissors in the terminal 3 inch.

Method of Use.—With the bottle three-quarters full of water, fix the bung firmly, with adhesive tape if necessary, and suspend it about 4 to 5 feet from the ground with the long tube dipping into a receptacle containing water.

Suction is exerted and controlled by manipulating the screw clips. The Ryle's tube or catheter is gently inserted into the patient's stomach by passing the tubing along one nostril after adequate lubrication of the tubing and *alæ nasi*. Cocainization is not usually necessary. When the end of the tube is felt to reach the posterior wall of the pharynx, the patient should take a mouthful of water and be ordered to swallow. Simultaneously, the tubing is pushed gently forward and usually passes down the pharynx into the œsophagus. Further progress is assisted by more draughts of water. When in position the tubing is attached by strapping to

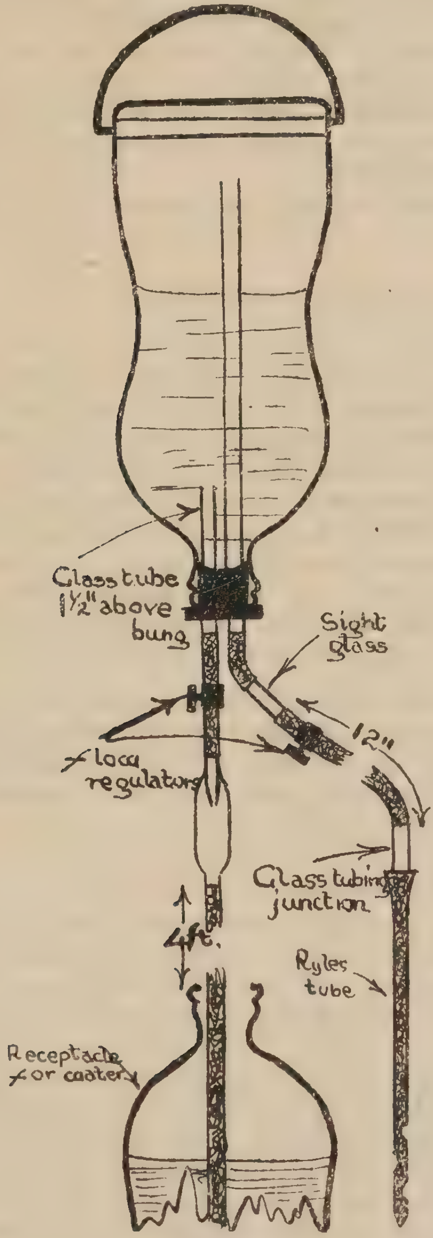


FIG. 20.

Transfusion equipment modified to exert continuous gastric suction.

the patient's cheek and also to the pillow, due allowance being made for head movement.

After Care.—Excoriation of the nostril is apt to occur after a time unless the tubing is changed occasionally from one nostril to the other. The bottle requires to be filled with water at intervals, as much gas is sucked from the stomach in addition to fluid and debris. Movement of the bottle from time to time prevents the exit tube from becoming clogged and if the bottle can be slightly tilted, so that debris collects in the opposite angle at the neck, clogging is not so frequent.

Whilst suction is in progress, the patient is allowed to take fluids freely by mouth.

ADMINISTRATION OF OXYGEN

General Principles

Oxygen therapy is essential for the treatment of anoxæmia, usually manifested clinically by cyanosis, which is found when there is injury to the respiratory apparatus from wounds, blast or gassing. The uses of oxygen in the Field are discussed on p. 9. A face-piece apparatus is essential if sufficiently high concentrations of oxygen are to be obtained. Neither a nasal catheter, nor a nasal tube on Tudor Edwards' spectacle frames, nor, least of all, an open funnel, provide oxygen in a concentration sufficiently high to be really effective. The standard Army issue is apparatus, oxygen, B.L.B. pattern (Fig. 12), which consists of the following :—

Masks, B.L.B., Nasal (consisting of face-piece, valve, I.R. bag and tubing), Regulator, pattern A (consisting of fine adjustment valve, and bobbin-type flowmeter), or pattern B (consisting of reducing valve, flowmeter, and pressure gauge) with adjustable spanner. Box, to hold above.

Instructions for Use

Before attaching the regulator to the oxygen cylinder open and close sharply the valve of the cylinder to remove any dust or grit that might be present. Screw the regulator into the cylinder valve, tightening flynut of the regulator by leverage provided on the cylinder key.

Do not admit a sudden rush of oxygen into the closed regulator, *i.e.* before opening the cylinder valve see that the outlet valve on top of the regulator is slightly open, then, having moderated the flow, close the outlet valve on the regulator until ready to administer.

To start the flow of oxygen open the main valve of the cylinder. Adjust the mask to fit the face snugly but in a manner comfortable to the patient. The mask is properly adjusted when the reservoir-rebreathing bag dilates and contracts with each respiration. The flow of oxygen can then be finally adjusted according to the colour of the patient's face. Either a blue colour of the lips and face or grey ashen colour indicates the need for oxygen and the return of a normal colour indicates that sufficient oxygen is being supplied. The minimum flow of oxygen required to maintain the desired effect should be used.

The desired concentration of oxygen depends on the regulation of the flow of oxygen in conjunction with the adjustment of the airports by means of the rotating sleeve on the connecting-regulating device. For example, experiments have shown that for a large to medium sized man the alveolar oxygen percentage will be as follows :—

With the oxygen flowing at 3 litres per minute with 2 holes open —45–55 per cent.

With the oxygen flowing at 5 litres per minute with 2 holes open —65–75 per cent.

With the oxygen flowing at 6–7 litres per minute with no holes open—92–95 per cent.

Later models have a Sorbo sponge expiratory valve instead of the metal connecting device with portholes ; with this model the full concentration of oxygen is continuously delivered.

With pattern A the flowmeter tube on the regulator must always be used in a vertical position, otherwise it does not register flows correctly ; as the pressure falls in the oxygen cylinder, so proportionately will the reading on the flowmeter, and a periodical adjustment of the flowmeter is necessary to maintain the flow of oxygen required.

To Sterilize the Apparatus

Remove the mask and bag from the connecting-regulating device and wash each part with soap and water ; rinse with clean water and boil for three minutes. All parts should be hung up to drain and dry. The utensil used for boiling should be equipped with a wire screen to prevent the rubber parts from coming in contact with the bottom which might be hot enough to cause damage.

No disinfectant or germicide should be added to the water as this may cause corrosion of the metal parts and damage to the rubber.

ANÆSTHETICS

Efficient anæsthesia is of great importance in the injured. There is a general impression that the anæsthetist will get better results with the anæsthetic to which he is accustomed than with some vaunted new preparation with which he is quite unfamiliar. Cyanosis must be avoided. Chloroform and spinal anæsthesia must not be employed. Pentothal has proved to be of value in cases of shock and hæmorrhage ; it has the advantage that it can be administered in the resuscitation ward, with no disturbance to the patient, by injecting the drug into the rubber transfusion tube towards the end of a blood or plasma transfusion ; the patient is unaware that an anæsthetic is being administered. Great care must be taken to limit the dose and to make the injection slowly, as these patients are extremely susceptible to barbiturates. A careful inquiry must also be made regarding the amount of morphia the patient has received and the time of the last injection. Patients previously treated with a sulphonamide compound also appear to require a smaller amount than usual. The usual five per cent. solution of pentothal is used and a dose of 0·3 g. to 0·8 g. will generally be sufficient to give adequate anæsthesia for an extra-abdominal operation. For intra-abdominal work a slightly larger dose may be required or the original dose followed by nitrous oxide, oxygen and minimal ether. If pentothal is given alone, some apparatus for giving oxygen under pressure must always be at hand to deal at once with any signs of respiratory depression.

Care and Maintenance of Army Refrigerator Equipment

Refrigerator Types

The following types of mobile refrigerators are provided for Home and Active Service :—

Type	*Engine*	*Vehicle*	*Capacity*	*Notes*
A (Figs. 13 and 14) (Wt. 15 cwt.)	JAP 4/2	15 cwt. Morris or 3-ton lorry	400 bottles in crates.	May be modified with extra insulation for use as a cool room in tropical climates. Capacity then 250 bottles in crates.
B (Wt. 9 cwt.)	JAP 2A	30-cwt. lorry	100 bottles not in crates.	For Home Service only. Used by blood collecting teams.
C (Wt. 10 cwt.)	JAP 2A	3-ton lorry	80 bottles not in crates.	Standard issue for use in all climates.
DC (Wt. 10 cwt.)	JAP 4B	3-ton lorry	Ditto	
E (Smithfield) (Fig. 15) (Wt.12¼ cwt.)	Petter or Wisconsin	3-ton lorry	Ditto	

When demanding service or spare parts either for refrigerators or engines the type of refrigerator and model of engine must be stated.

Principles of Refrigeration

All refrigerators in use with the Army Blood Transfusion Service work on what is known as the " Vapour Compression System ". The system employs a liquid under pressure which expands in the cooling coils. During this expansion the liquid takes in heat from its surroundings and in so doing is converted into vapour. The vapour is then compressed and recondensed into a liquid ready for a further cycle.

The essential components of such a system are shown diagrammatically in Fig. 21 :—

1. Cooling coils or " Evaporator " (Fig. 21 (a).
2. Compressor, or pump, to extract the vapour from the evaporator and compress it, Fig. 21 (d).
3. Condenser, where the compressed vapour is cooled and subsequently liquified, Fig. 21 (f).
4. Regulator or pressure-reducing valve which allows the correct amount of liquid refrigerant to re-enter the cooling coils, Fig. 21 (e).

Although the principle of the system is common to all, the application varies slightly with the different types.

Types A and A modified are fitted with a petrol engine, electric generator and storage batteries. The generating set, for battery charging, is driven by a small petrol engine that needs to be started by hand (Fig. 13). The refrigerating machinery, however, is driven by an electric motor which derives its power from the storage batteries and is entirely automatic in operation, stopping and starting as required by the temperature of the storage compartment. Cooling of the storage compartment is done by means of cooling coils arranged on one wall and a fan which circulates the air in the storage chamber over these cooling coils. *Experience has shown that the most economical way of operating these types is to run the generating set as a daily routine for a period of time, sufficient to bring every cell in the storage batteries to full charge.* The correct charging rate during this operation is 12 amps. The state of the battery is determined by use of the hydrometer supplied with the tool kit ; each cell should be checked in turn and when fully charged the reading on the hydrometer should be 1·285. The refrigerating machinery will then look after itself for the remainder of the 24 hours. In order to check the operation of the refrigerator a thermometer, two gauges and a window in the pipe from the condenser to the regulator are provided (Fig. 14). When operating normally the temperature of the storage compartment should be between 38° F. and 42° F. (4°–6° C.) (Type A modified 55°–60° F.). Evaporator gauge should read *approximately* 30° F. below the temperature of the van. The condenser gauge should read *approximately* 10° F. above the outside air temperature. The window in the liquid line should be clear and free of bubbles. The temperature scales on the gauges are the outside red figures, and it is important to note that gauge readings and the appearance of the liquid in the window are only significant when the refrigerating machine is running and has had time to settle down to normal working.

Types B and C have neither electrical apparatus nor any automatic instruments. The compressor is run by a small petrol engine which has to be started and stopped by hand as required. The cooling coils in these types do not cool the air in the storage compartment, but are immersed in a water jacket which surrounds it. When the machine is running the water jacket is converted into ice

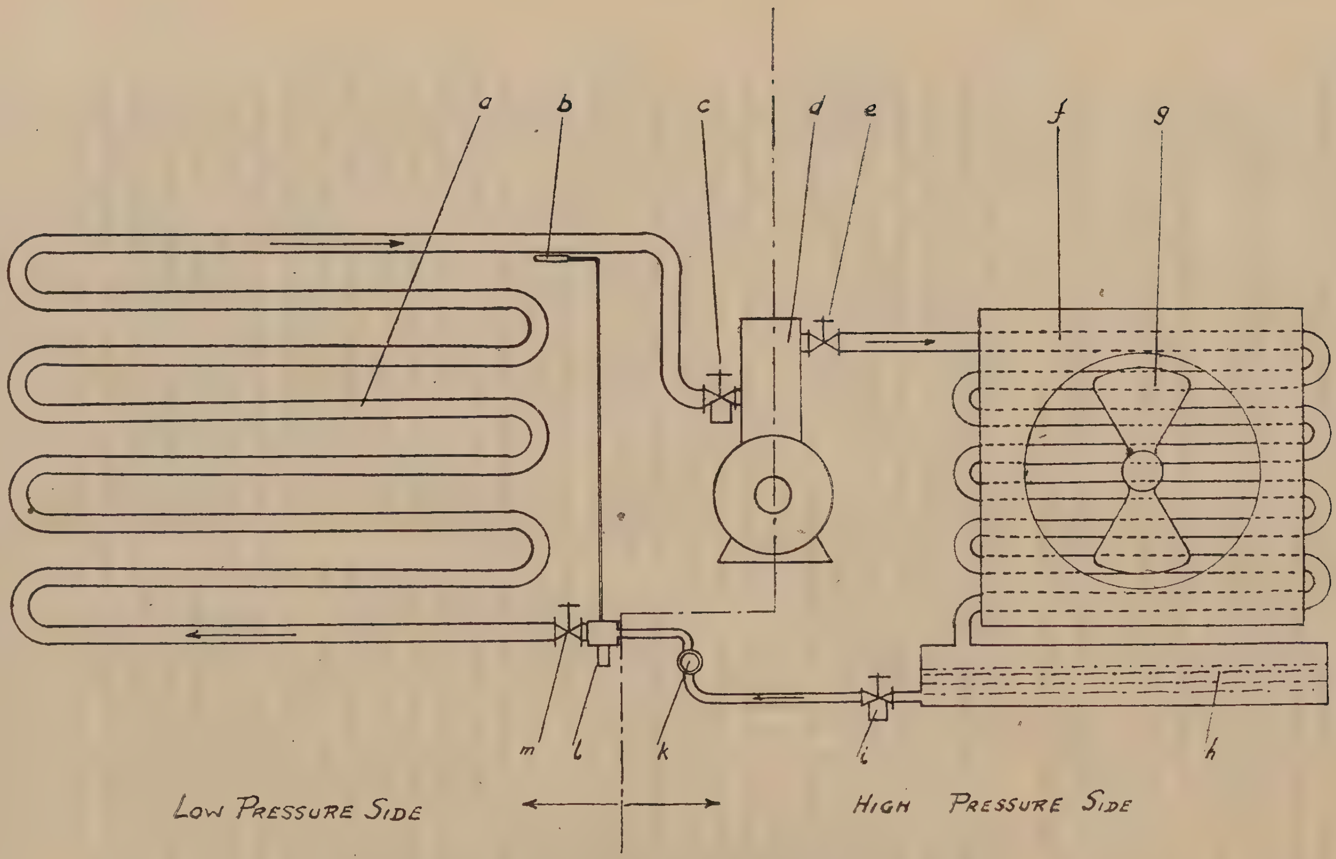


DIAGRAM OF REFRIGERATING SYSTEM.

Fig. 21.

Diagram to illustrate principles of refrigeration. (*a*) Evaporator or cooler. (In the B, C, DC and E types, this is immersed in water.) (*b*) Regulator bulb. (*c*) Suction stop valve and strainer. (*d*) Compressor driven by petrol engine or electric motor. (*e*) Delivery stop-valve. (*f*) Condenser. (*g*) Fan. (*h*) Liquid receiver. (*i*) Liquid stop valve and strainer. (*k*) Window. (*l*) Regulator. (*m*) Regulator stop-valve.

and as soon as this is complete the machine can be stopped. The ice so formed gives a big reserve of cold. The ice jacket maintains a temperature of 38°–42° F. (4°–6° C.) within the cabinet.

These machines are also equipped with thermometer, two gauges and a window. The thermometer registers the temperature of the water in the jacket and is marked in the Fahrenheit scale. The temperature recorded when the machine is in use should therefore always be 32° F. (freezing point of water). As soon as the temperature begins to rise above this figure the machine should be started, but if it falls below this figure the machine should be stopped to prevent any under-cooling of the ice. When the machine is running and settled down the window should be clear and free of bubbles, the evaporator gauge should read 8°–10° F. below the temperature of the water sleeve and the condenser gauge should read 25°–30° F. above the temperature of the air being drawn over the condenser by the fan.

Type DC.—This is an improved version of the Type " C " Refrigerator. The cabinet and compressor are identically the same, and naturally the method of operation is the same. The unit has, however, been furnished with a more powerful engine (J.A.P. 4B) and a more efficient condenser which is fitted above the refrigerating machine. A different type of regulator, known as Hall's Gas Control Unit, is also fitted. This regulator has the advantage that it can be dismantled and have new parts fitted if necessary. It is *never* necessary to change the whole regulator. The window for observing the liquid refrigerant is built into this regulator. The correct gauge readings are : Evaporator Gauge—approximately 8°–10° F. below the temperature of the water sleeve. Condenser Gauge—approximately 10° F. above the air being drawn over the condenser.

The Type DC can be distinguished from the Type C by the fact that the former has a condenser with separate fan mounted immediately above the compressor.

Type E (" *Smithfield* ") (*Fig.* 15).—This is different from the B, C and DC models, although the fundamental idea is similar. The cabinet has the same capacity as the Type " C " and is approximately the same length and width but is considerably taller.

Cooling of the storage compartment is done by means of a water jacket surrounding it as in the " C " type of refrigerator, but in this case the water jacket is not frozen. Ice is made in a separate compartment situated above the cabinet and the cold water produced by the melting ice circulates down through the water jacket and then gradually rises again by convection as it warms up. A cap is situated on top of the ice-making compartment and by removing this cap a scale can be seen which indicates how many pounds of ice remain. In order that this scale shall read correctly it is necessary that the water level should just reach the zero mark on the scale before any refrigeration is done at all. When ice is made its expansion displaces some of the water in the ice compartment into the measuring compartment causing the water level to rise and indicate on the scale how much ice has been made. To obtain access to the regulator it is necessary to remove the lid through which the measuring compartment protrudes.

The machine is fitted with two automatic cut-outs (Fig. 15). These are connected to the magneto of the engine. One is a high-pressure cut-out and will stop the engine should any excessive pressure build up in the condenser. The other is a low-pressure cut-out and is normally set to stop the engine when about 40 lb. of ice has been made. If the engine will not start when it is wished to increase the reserve of ice, this cut-out should be examined, and, if the contacts are touching, it will not be possible to start until some of the ice has melted unless the wire leading from this cut-out to the magneto be disconnected.

The general method of working is the same as for types B and C and the same aids to checking are provided, namely, two gauges, a window in the liquid line, and a thermometer in the ice-making compartment. The correct gauge readings after the machine has settled down are :—Evaporator Gauge : Approximately 15° F. below the temperature showing on the thermometer. Condenser Gauge : Approximately 25° F. above the temperature of the air being drawn over the condenser.

Repairs are carried out in the same way as for types B and C refrigerators except that the technique of adding refrigerant is different in that no charging pip is fitted to the regulator stop valve (*see* p. 71).

Maintenance

(*a*) *Types A and A modified :* routine points to observe at regular intervals :—

1. Acid in batteries of correct specific gravity (1·285) and the level such that the tops of the plates are covered.

2. Oil in the engine sump completely changed once a fortnight. Level to be checked daily.

3. Generator and electric motor greased weekly.

4. Whole generator set complete with engine to be removed monthly, cover removed from generator commutator and inside of generator well cleaned.

5. Carbon brushes of generator, motor, condenser fan and evaporator fan to be checked monthly and replaced if worn to half their normal length. Commutator to be cleaned with rag dipped in petrol or fine glass paper.

(*b*) *Types B, C, DC and E* (*Smithfield*).

1. Level of oil in engine to be checked before starting. Oil to be completely changed once a fortnight. Air filters when fitted to be cleaned as stated in maker's instructions marked on them.

2. Level of water in jacket of B, C and DC types to be checked weekly. Water must cover cooling coils ; these can be seen through the small plated inspection plate on top of the cabinet. In the E (Smithfield) type the water level should be checked whenever the refrigerator is not in use ; the level should come to the zero mark on the scale when there is no ice on the coil.

3. Condenser fins to be kept clean and free of dust.

Repairs

A small tool kit is provided, for such small running repairs as the R.A.M.C. orderlies are capable of doing. Major breakdowns or obscure troubles should be dealt with by R.E. personnel only.

The most common refrigerator troubles cause similar symptoms in all five types of refrigerator.

1. *Shortage of Refrigerant.*—The evaporator and condenser gauges appear lower than usual and bubbles are seen in the window of the liquid line. The remedy is first to find the leak by means of the special test lamp provided and then to add refrigerant from the spare bottle until normal observations are obtained. To add refrigerant, attach the charging pipe supplied with the tool kit to the pip on the regulator stop valve and the other end of the pipe to the spare gas bottle, having first made sure that the regulator stop valve is screwed out to its fullest extent. Having connected the pipe as above, screw in the stop valve spindle two full turns, open valve on gas bottle and start machine. Watch window and when it fills up shut off valve on gas bottle and leave machine running. Bubbles will probably reappear after a short while. Reopen valve on bottle and continue as before. Repeat this operation until the window remains full and the gauges show normal readings. Shut valve of gas bottle, screw out spindle of regulator stop valve to fullest extent, disconnect pipe, replace pip and valve stem cover (Fig. 14). With the E (Smithfield) Refrigerator there is no charging pip on the regulator stop valve. The method of charging therefore is as follows :—

Attach one end of the charging pipe to the gas bottle and tighten up. Attach the other end to the pip on the end of the gauge block, having first shut the evaporator gauge shut-off valve. Blow a little gas through the pipe and then tighten the end attached to the pip. Open the gauge shut-off valve and the tap on gas bottle. Continue to let the gas flow in until bubbles in the window disappear, then shut tap on gas bottle. Repeat if necessary. When bubbles finally disappear, close tap on gas bottle, shut the gauge shut-off valve, remove charging pipe and replace cover on pip. Finally, reopen the gauge shut-off valve. *When charging in this way, the gas bottle must never be held upside down* so that the liquid refrigerant flows into the machine. Always keep the bottle upright with the tap on top or damage may be caused to compressor valves.

2. *Choked Liquid Strainer.*—Same signs as in 1, but in addition the small pipe from the liquid strainer feels colder than the large pipe from the condenser to the strainer. To remedy, screw in liquid stop valve as far as possible; run machine until evaporator gauge reads 2 lb. per square inch. Screw in regulator stop valve spindle as far as possible, undo four nuts under the strainer and pull out the basket. Clean with petrol and finish if possible with methylated spirits. Replace strainer, slack off nut holding liquid line to regulator, open liquid stop valve, tighten up nut on regulator, open regulator stop valve, replace stop valve caps and start machine.

3. *Dirty Condenser.*—This will be indicated by higher condenser gauge reading than usual. Condenser fins should be thoroughly cleaned with brush or compressed air.

4. *Choked Regulator.*—The signs of this are as in 1 above, except that the window will be *full* of liquid. Proceed as in 2, but instead of removing strainer, remove regulator, clean with petrol and methylated spirits and replace.

In addition the types A and A modified may develop some minor electric fault. The commonest are :—

1. *Main Fuse Gone.*—Replace and check compressor to see that it is not stiff, thus causing an overload.

2. *Thermostat not Working Correctly.*—If temperature is above the limits given previously, remove cover from thermostat and see if the two points are making contact; if not, check the setting on the scale provided. If this is correct wedge the two points together and operate the machine by hand from the main switch until new thermostat is fitted.

3. *Generator Set will not Record any Charge on the Ammeter.*—Remove fuse in switch box, examine and replace if necessary with 15-amp. fuse.

IMPORTANT NOTES

Engines.—(*a*) If red petrol (containing lead) is used for any engine used with the various types of refrigerator, lubricating oil in the proportion of ½ pint of oil to 2 gallons of petrol must be mixed with the petrol. Alternatively a good upper cylinder lubricant can be added to the petrol in the proportion recommended by the makers.

(*b*) Most engines are now issued filled with HD.30 oil and a note to this effect is painted on them. Should it be necessary to change the grade of oil the engine sump must be washed out carefully with petrol before refilling with the new grade. The HD.30 marking must then be deleted.

APPENDIX

SCHEDULE OF STANDARD EQUIPMENT OBTAINABLE FROM ARMY BLOOD SUPPLY DEPOT

General Notes

This list is compiled to assist in the composition of indents.

The code letters are designed to facilitate orders by telegram and to avoid ambiguity; they should be quoted on all indents.

Telegraphic Address: TRANSFUSE BRISTOL.

Telegrams should give code letter first, followed by number required, *e.g.* AA 50 VA 1 MC 100 would be interpreted as

Giving sets, overseas pattern	: 50
Viscaps No. 1A	: 1 tin of 5 gross
Adaptors	: 100

STANDARD EQUIPMENT OBTAINABLE FROM ARMY BLOOD SUPPLY DEPOT

(A) **Assembled Equipment**

Code Letter	*Article*	*Notes*
AA	GIVING SET, OVERSEAS PATTERN, for use with fluid plasma or topped-up blood supplied from Army sources (Fig. 10, p. 37).	Issued with needle, wrapped in cellophane, sterilized ready for use and contained in gold lacquer tin box. Ordinary issue, one per two bottles of blood or fluid plasma contained in K N S type bottle corked with white flanged bung. Designed to be salvaged and reconditioned at Base.
AB	GIVING SET, OVERSEAS PATTERN, for use with dried plasma supplied from Army sources.	Same components, wrapping and tin box as above, with addition of one white flanged bung for insertion in bottle after reconstitution. Designed to be salvaged and reconditioned at Base.
AC	GIVING SET, HOSPITAL PATTERN, for administration of fresh blood or of glucose-saline, and of blood or plasma supplied from E.M.S. sources (Fig. 11, p. 38).	One unit consists of set complete with needle. Issued as: (*a*) Tin box containing six units (AC), each wrapped separately in calico envelope together with glass beads.

(A) **Assembled Equipment**—*continued*

Code Letter	*Article*	*Notes*
AD	GIVING SET, HOSPITAL PATTERN—*contd.*	(*b*) Single unit complete with needle, wrapped in calico envelope and glass beads (AD).
ADA		(*c*) Similar single unit wrapped in cellophane, with no beads, for administration of crystalloid solutions (ADA).
		Designed to be reconditioned for repeated use. Set will fit K N S or screw-cap type bottle. BOTTLES MUST BE INDENTED FOR SEPARATELY.
AE	TAKING SET, UNIVERSAL PATTERN (Fig. 11, p. 38).	One unit consists of set complete with needle. Issued as : (*a*) Tin box containing six units wrapped separately in calico envelope (AE).
AF		(*b*) Single set wrapped in calico envelope (AF).
		Designed to be reconditioned for repeated use. Set will fit K N S or screw-cap type bottle. BOTTLES MUST BE INDENTED FOR SEPARATELY.
AG	TAKING AND GIVING, COMBINED BOX.	Tin box containing two each of Hospital Pattern Giving Set and Universal Taking Set and ¼ lb. spare beads. Issued as part of the equipment contained in "Box Apparatus Transfusion and Infusion. Field Pattern."
AH	APPARATUS, TRANSFUSION AND INFUSION FIELD PATTERN BOX (Fig. 6, facing p. 32).	Issued to Field Units, Troopships, Hospital Trains. (For contents *see* p. 34. For scale of issue *see* p. 35).
AI	APPARATUS, TRANSFUSION AND INFUSION HOSPITAL PATTERN BOX.	Issued to General and Military Hospitals. (For contents *see* p. 34. For scale of issue *see* p. 35.)
AJ	APPARATUS, TRANSFUSION AND INFUSION, AIRBORNE PATTERN BOX.	For contents *see* AMS Form 11A.

(B) Component Parts of Assembled Equipment

GIVING SETS, OVERSEAS PATTERN (AA AND AB)

Code Letter	*Article*	*Notes*
MC	Adaptor.	
CPD	Box, tin, gold lacquered.	
RE	Bung, white flanged, BT4A.	Issued with each bottle of Dried Plasma.
MA	Bush brass (speed regulator).	Screw-clip regulator (MH) is alternative.
CPK	Calico, for wrapping steel parts.	Issued as packets of 4 yds. × 36 in. Amounts required: tubing mount, 3 in. × 3 in.; 9-in. piercing needle, 18 in. × 1½ in.; 1 in. piercing needle, 5 in. × 3 in.
CPJ	Cellophane, plain, transparent, 10 in. × 15 in.	Issued as sheets. One sheet a set. Inner wrapping.
CPV	Cellophane, moisture proof, 10 in. × 15 in.	Issued as sheets; one sheet per set. Outer wrapping.
AK	*Drip counter, assembled, complete, consisting of:*	
RD	Bung BT5, 1 × 5 mm. hole.	
GA	Filter, cover, glass.	
GC	Tube, 2-in., shaped glass.	
VA	Viscap No. 1a with $\frac{5}{16}$ in. hole.	Issued in tins containing 5 gross.
AJ	*Mantle filter, assembled complete, consisting of:*	
RD	Bung BT5, 1 × 5 mm. hole.	
GA	Filter, cover, glass.	
MF	Mantle.	
GB	Tube, glass, with lateral hole.	
VA	Viscap No. 1a. With $\frac{5}{16}$-in. hole.	Issued in tins containing 5 gross.
NC	Needle, Blood Transfusion.	
NB	Needle, piercing, long, 9 in.	
NA	Needle, piercing, short, 1 in.	
MH	Regulator screw-clip.	Alternative to Bush brass (speed regulator).
RJ	Tubing IR, ¼-in. with ⅞-in. bore.	4 ft. 1 in. a set (including 6 in. required for non-return valve).
MB	Tubing mount.	

(B) Component Parts of Assembled Equipment—*continued*

Code Letter	*Article*	*Notes*
AL	*Valve, non-return, assembled complete, consisting of :*	
RF	Dam, rubber	Issued in tins containing 7 ft. × 5 in. 1 foot makes 120 valves.
GD	Filter, air, enclosing.	
GE	Valve-tube, glass, with side hole.	
VB	Viskring No. 00	Issued in tins containing 10 gross.
MG	Wire, copper, for binding joints.	Issued as reels by weight 1 lb.

Giving Set, Hospital Pattern (AC and AD)

MC	Adaptor.	
GJ	Beads, glass, for filter	One test-tube full (½ oz.) a set 10 lb.=320 sets.
CPE	Box, tin, slip lid, 11 in. × 4 in. × 4 in., for containing units of 6.	
RC	Bung, BT3, Red, 2 × 5 mm. holes.	
MA	Bush brass (speed regulator)	Screw-clip regulator (MH) is alternative.
GK	Drip counter, composite, all glass.	EMS pattern.
CPL	Envelope, calico, for wrapping.	
GH	Filter, air-inlet.	
NC	Needle, Blood Transfusion.	
MH	Regulator, screw-clip	Alternative to Bush brass (speed regulator).
GG	Tubing, glass, fluted, 2½-in. lengths.	
GF	Tubing, glass, 9½-in. lengths.	
RJ	Tubing, IR, ½-in. with ⅛-in. bore.	4 ft. 1 in. a set (including 6 in. required for air filter).
MB	Tubing mount.	

Taking Set, Universal Pattern (AE and AF)

CPE	Box, tin, slip lid, 11 in. × 4 in. × 4 in., for containing units of 6.	
RC	Bung, IR, Red, 2 × 5 mm. holes.	
MD	Clip, Mohr's	Optional ; 2 a set. For use with large bleeds.
CPL	Envelope, calico, for wrapping.	
GH	Filter, air-inlet.	
NC	Needle, Blood Transfusion.	
GL	Test-tube, 2½ in. × ½ in. cover for needle.	
GM	Tubing, glass, 2½ in. lengths	3 a set ; one for window ; two for bung connections.
RK	Tubing, IR, 7/16 in., with 3/16 in. bore.	2 ft. 6 in. a set.

(C) **Equipment—Separate Entities**

Code Letter	*Article*	*Notes*
BA	Bottles, Blood Transfusion, KNS type.	Used for blood and fluid plasma prepared at Army Blood Supply Depot or Base Transfusion Units. Not recommended for ordinary medical unit's own use.
BC	Caps, clip, for bottles KNS	
BF	Bands, for bottles	
RH	Discs, IR, white, 35 × 1·5 mm.	Liners for Caps clip, KNS.
BB	Bottles, Blood Transfusion, screw-cap type.	Used for dried plasma, distilled water and crystalloid solutions. Recommended for ordinary medical unit's own use in taking and giving of blood.
BF	Bands, for bottles	
BD	Caps, screw, aluminium	
RG	Discs, IR, Red, $1\frac{7}{16}$ in. × $\frac{3}{16}$ in. for screw caps.	
BE	Bottles, Dispensing, 4-oz. medical flat, specially treated for autoclaving.	For preparation sodium citrate or saline in 100 c.cm. amounts.
ND	Cannula, Blood Transfusion.	Issued as part of Unit I1248 equipment.
CPJ	Cellophane, plain transparent, 10 in. × 15 in.	For wrapping Overseas sets. Issued in sheets. One sheet per set. Issued only to Base Transfusion Units, General and Military Hospitals.
CPV	Cellophane, moisture proof, 10 in. × 15 in.	
CPW	Cellophane, plain transparent, 10 in. × 20 in.	For wrapping Glucose-saline sets (ADA). Issued in sheets, etc., as for other cellophane.
CPX	Cellophane, moisture proof, 10 in. × 20 in.	
CPF	Crates, wire—to hold 10 bottles.	Ordinarily issued only to Base and Field Transfusion Units.
NC	Needle, Blood Transfusion	Gauge 15/10.
ME	Stands, transfusion, telescopic	For suspending transfusion bottles. Ordinary issue: Field Transfusion Units, 6; Military Hospitals, 3 per Hospital pattern box (p. 34).
MG	Stands, Transfusion, Stretcher, wooden.	For suspending transfusion bottle during carriage of stretcher. Ordinarily issued only to Base and Field Transfusion Units.
CPY	Tape, Adhesive (black, blue or colourless), rolls.	Rolls ½ inch × 72 yards. For sealing tins containing sets when no cellophane available. Ordinarily issued only to Base Transfusion Units.
VC	Viscaps, No. 5, white, with ⅞ in. hole.	Used by Army Blood Supply Depot and Base Transfusion Units for sealing blood-taking bottles for extensive bleeds. Tins contain 2½ gross.

(D) Products

Code Letter	Article	Notes
(a) Blood and Blood Products :		
TIA	Blood, pint bottle	Indent should state with or without giving set (AA).
TIB	Plasma, fluid, pint bottle	Ditto.
TIC	Plasma, dry, pint bottle	Indent should state with or without giving set (AB) and with or without saline for reconstitution.
(b) Crystalloids and Water :		
TID	Distilled Water, pyrogen free, pint bottle.	For general use.
TIE	Glucose-saline, Isotonic (0·3 per cent. NaCl. 3·3 per cent. glucose), pint bottle.	Indents should state with or without giving set (ADA).
TIEA	Glucose-saline, Isotonic (0·425 per cent. NaCl. 2·5 per cent. glucose), pint bottle.	
TIEB	Physiological saline (0·85 per cent. NaCl), pint bottle.	
TIEC	Glucose, Isotonic (5 per cent.), pint bottle.	
TIED	Glucose, Hypertonic (10 per cent.), pint bottle.	
TIEE	Hypertonic, glucose 5 per cent. in physiological (0·85 per cent.) NaCl, pint bottle.	
TIEF	Glucose, Hypertonic (50 per cent.), 50 c.cm. in 4 oz. medical flat.	
TIF	Trisodium citrate, 3 per cent., 100 c.cm. 4 oz. medical flat.	For blood-taking bottles and alkalinization.
TIFA	Acid-citrate-glucose solution (2 per cent. disodium, citrate 100 c.cm. ; 15 per cent. glucose, 20 c.cm.).	Acid citrate for taking blood for store (see p. 43).
(c) Grouping Serum :		
TIL	Serum, High titre, Group A (Anti-B) Dry, 1 c.cm. tubes.	For blood-grouping tests. Stable without refrigeration. Sufficient for 20 tests.
TIM	Serum, High titre, Group B (Anti-A). Dry, 1 c.cm. tubes.	

(E) Packing

(With dimensions, cubic content and weight)

Code Letter	Article	Contents	Weight, full
CPA	Box, Wood, 14 compartments for plasma (27½ in. × 11½ in. × 11 in. ; 2 cu. ft. ; 20 lb.) (Fig. 7).	(*a*) 14 fluid plasma ; 7 sets.	68 lb.
		(*b*) 7 dried plasma ; 7 saline ; 7 sets	48 lb.
CPA 1	Ditto, without compartments (18 lb.).	(*a*) 20 fluid plasma ; 10 sets.	77 lb.
		(*b*) 10 dried plasma ; 10 saline ; 5 sets.	60 lb.

(E) **Packing**—*continued*

Code Letter	*Article*	*Contents*	*Weight, full*
CPO	Box, Wood, No. 6, General, for glucose-saline (19½ in.×10½ in.×13½ in.; 1½ cu. ft.; 15 lb.)	20 saline; 5 sets	65 lb.
CPC	Box, Wood, No. 5, General, (26½ in.×16½ in.×14 in.; 3½ cu. ft.; 26 lb.)	(*a*) For Apparatus, Tr. and Inf. Hospital pattern (A.M.S. Form 27, *see* p. 34).	68 lb.
		(*b*) For bulk packing, 36 saline.	121 lb.
CPP	Box, Wood, No. 2, General, (3 ft. 8 in.×1 ft. 11 in.×1 ft. 8 in.; 12 cu. ft.; 59 lb.).	For bulk packing, saline 144; sets 36.	406 lb.
CPB	Box, Wood, for Apparatus, Tr. and Inf. Field pattern (29 in.×12 in.×12 in.; 2·4 cu. ft.; 26 lb.).	A.M.S. Form 88A; (*see* p. 34).	76 lb.
CPQ	Box, Wood, for Field Transfusion Unit equipment (26 in.×12 in.×12½ in.; 2·2 cu. ft.; 26 lb.).	(*See* p. 28).	46 lb.
CPR	Box, Wood, for Airborne Resuscitation Equipment (27½ in.×10½ in.×12 in.; 2 cu. ft.; 21 lb.).	A.M.S. Form 11A.	54 lb.
CPS	BASKET, Wicker, with Firthflex inserts, Airborne pattern (Ht. 15 in., diameter 13 in.; 1 cu. ft.; 9 lb. (Fig. 9).	8 plasma; 4 sets.	30 lb.
CPV	Inserts, Firthflex, for C.P.S.	—	—
CPG	Box, INSULATED, with ice insert, for air transport blood (24¼ in.×20 in.×12½ in.; 3½ cu. ft.; Wood, 36 lb.; Metal, 63 lb.) (Fig. 8).	20 blood; 2 crates 10 sets	(*a*) Wood: 103 lb. (*b*) Metal: 130 lb.
CPU	Box, INSULATED, with ice insert, for air and road transport blood (18¾ in.×11¾ in.×10¾ in.; 1¼ cu. ft.; 20 lb.).	10 blood; 5 sets	56 lb.
CPH	Ice Inserts (14 in.×8¾ in.×1¼ in.) spare	For either CPG or CPU.	
CPT	Box, INSULATED, without ice insert, for hand carrying blood (7 in.×12 in.×14½ in.; 1,197 cu. ins.; 11 lb.).	3 blood	18½ lb.
CPM	Carton, waterproof, cardboard (Ht. 9 in.; diameter 4 in.; 113 cu. ins.; 3 oz.).	1 plasma	2 lb. 10 oz.
CPN	Container, Triple carton, for pack or hand carrying (18 in.×14 in.×4 in. diameter 678 cu. in.; 3 lb.)	4 plasma 2 sets	14 lb.

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